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SERIE RESEARCHMEMORANDA

DEMAND AND SUPPLY OF NATURAL RUBBER

Part I (updated) and

Part II

Hidde P. Smit

Researchmemorandum 1982- 29 November 1982

VRIJE UNIVERSITEIT
EKONOMISCHE FAKULTEIT
AMSTERDAM

DEMAND AND SUPPLY OF NATURAL RUBBER

part I (updated) and
part II

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PREFACE

The study on production policy and market conditions for natural rubber has been carried out hoping to reduce the uncertainty of natural rubber producers regarding the future of their product. The study provides an analysis of the demand for all types of rubbers and of the production of natural rubber. It draws conclusions about the effects of production policies on market shares and prices for natural rubber.

The analysis on demand prospects was conducted in 1978. At the time, I was a staff member of the United Nations' Economic and Social Commission for Asia and the Pacific (ESCAP) in Bangkok. There the project started in cooperation with Mr. Moeljono Partosoedarso and Mr. D.P. Elliott. A follow-up study was commissioned to me after my return to the Economic and Social Institute of the Free University in Amsterdam. This follow-up concerned the updating of the rubber demand analysis, together with a new analysis of supply, and combining these studies into a complete market share and price analysis. Two - policy oriented - reports were already prepared for ESCAP, while a book describes the methodology adopted in the research. I am most grateful to ESCAP for commissioning the research work, which could be financed through the kind assistance provided by the Netherlands Government to ESCAP.

Even before ESCAP asked me to do the first part of the study, it was Mrs M.J. 't Hooft-Welvaars who drew my attention to the rubber world. She has guided me ever since in a way which was most stimulating and profoundly deepened my insight into many parts of the world rubber economy. I like to use this opportunity to express my sincere appreciation to her. I would also like to express my thanks to my scientific supervisors Prof.dr. H. Linnemann and Prof.dr. F.C. Palm for continuously giving the stimulating guidance of their knowledge.

It is impossible to do an adequate commodity analysis without receiving information and comments from people to whom the commodity studied is

their daily concern. I would like to thank all staff members of the ministeries and institutions concerned, in Malaysia, Indonesia, Thailand and Sri Lanka for all their assistance. I am grateful for the advice I received from the staff of rubber and tire companies. Further, I gratefully acknowledge all suggestions from staff of such international organizations as the Economic and Social Commission for Asia and the Pacific, the International Rubber Study Group, the Association of Natural Rubber Producing Countries, the International Natural Rubber Organization, the World Bank, the Food and Agriculture Organization and United Nations's Conference on Trade and Development.

I owe a special word of thanks to Dr. P.W. Allen of the Malaysian Rubber Producers' Research Association and to Mr. Ph.J. Watson of the International Rubber Study Group. Mr. Watson also kindly helped in improving the English text of the book.

Finally, I am most grateful to everyone assisting me on a more regular basis with regard to the data and computational work and with the typing of the manuscript. Without this assistance, as subsequently provided by Mr. A.F. Creutzberg, Mrs. Naree Boontherawara, Mr. E.P. Kroon and Mr. M.A. van Erven, this study would not have been possible.

1. INTRODUCTION

1.1 THE WORLD RUBBER ECONOMY: NATURAL RUBBER (NR) AND SYNTHETIC RUBBER (SR)

The growth of the world rubber economy was extremely rapid up to 1973 (cf. table 1.1), mainly owing to demand-pull, especially in the automotive sector. A major part of rubber demand arises in the automotive industry, primarily for tires but also to some extent for other automotive parts. The automotive industry in Western Europe and Japan enjoyed high rates of growth during the decade prior to 1973 because of economic growth and rapid penetration of passenger cars. In North-America automotive use on a large scale had developed long before, but up to 1973 it continued to show a steady increase.

The oil-crisis of 1973 with its quadrupling of crude oil prices, as well as further heavy price increases of oil towards the end of the seventies had a sharp impact on both the demand and the supply side of the world rubber economy. Increased prices of gasoline and doubts as to future availability of oil affected purchase and use of cars and commercial vehicles. This was enhanced by worsening traffic congestion and environmental issues. Automotive use was further influenced by a serious economic recession starting in 1974-1975 and by the acceleration of world inflation. The drastic measures taken to combat inflation and their limited success thus far deepened the already existing doubts about the long-term future of world development in general and the rubber industry in particular.

Added to the effects of the automotive sector, changes in the structure of the rubber sector itself were also substantial. Up to the Second World War, NR enjoyed a near-monopoly position; this position started to be challenged by SR in the 1940's as a result of war-time needs. Since the Second World War, NR's-share in total world consumption has decreased steadily to about 30 percent (cf. table 1.1) as a consequence of technological evolution of synthetic rubbers, improved competitiveness due to reductions in relative costs and better marketing methods of SR producers, vertical integration in the SR producing and consuming industries and insufficient availability of NR.

Table 1.1 *Natural rubber (NR) in the world rubber economy; some key figures*

	Aggregate rubber consumption a)	Consumption of NR a)	Share (%) of NR 100*(2)÷(1)	Price of NR b)
	(1)	(2)	(3)	(4)
1960	4,495	2,100	46.7	0.84
1961	4,710	2,160	45.9	0.65
1962	5,115	2,255	44.1	0.63
1963	5,350	2,265	42.3	0.58
1964	5,825	2,380	40.9	0.56
1965	6,190	2,450	39.6	0.57
1966	6,780	2,545	37.5	0.52
1967	6,805	2,535	37.3	0.44
1968	7,650	2,780	36.3	0.44
1969	8,270	2,910	35.2	0.58
1970	8,625	2,990	34.7	0.46
1971	9,280	3,095	33.4	0.40
1972	9,960	3,230	32.4	0.40
1973	10,980	3,405	31.0	0.79
1974	11,970	3,520	29.4	0.87
1975	10,395	3,370	32.4	0.66
1976	11,420	3,505	30.7	0.87
1977	12,330	3,715	30.1	0.92
1978	12,495	3,725	29.8	1.11
1979	12,995	3,870	29.8	1.42
1980	12,425	3,760	30.3	1.63
1981	12,165	3,730	30.7	1.25

Notes: a) = in 1,000 tonnes
b) = US $ per kg (RSS1), New York.

Source: Rubber Statistical Bulletin, several issues, IRSG, London.

In the second half of the 1960's, the tendency in the tire industry to substitute SR for NR came to a halt in Western Europe due to the introduction of the radial tire. The radial tire uses more NR than the convential tire, which had been absorbing only a marginal NR content in the 1960's. However, the radial tire lasts 50 to 100 percent longer than the conventional tire. In the 1970's the radial tire also penetrated in North America and Japan. The consequent reduction in the number of tires used during the life of a car or commercial vehicle has a major impact on rubber use in the automotive sector. The increase in NR content is extremely beneficial to NR producers at the expense of the SR industry, which has been hard hit by the reduced demand due to the combination of lower SR content per tire plus lower tire output.

The negative influence of the introduction of radial tires on the SR industry became even more pronounced in 1973 because the quadrupling of oil prices created a change of major proportion in the cost structure of SR, which depends heavily upon petrochemical feedstocks. NR was far less affected on the cost side because in its case only fertilizers, yield stimulants and wages are influenced by oil prices and inflation. The competitiveness of NR appears to have strengthened owing to these changes in relative production costs.

Production possibilities of NR have improved remarkably as a result of research and development efforts pursued during the past 20 years. High yielding varieties of trees, improved tapping and processing techniques, technically specified rubbers and other marketing aspects have given and can still give huge productivity increases over the next decades if applied on a large scale. A new barrier to further increasing NR production in Malaysia, however, proved to be insufficient availability of labour for tapping and other production activities. A major reason behind this is the pull by the industrial areas.

Recently, NR production in most countries has declined dramatically because of the low price of NR since the middle of 1981. In particular in the smallholders sector, farmers try to find other sources of income to earn a living. In late 1981, and 1982, NR prices reached such a low level that the bufferstock manager of the International Natural Rubber Agreement (INRA) intervened in the market, trying to prevent excessively low price levels.

From many sides it has been argued, that INRA should try to arrive at price stabilisation not so much around the price trend, but, far more, at a level which is remunerative to the farmers and that the current bufferstock agreement does not provide for intervention at such a scale. The current low levels not only have short-term effects, but also reduce eagerness to replant old rubber area with high yielding trees because of doubts concerning the long-term outlook for NR, let alone to extend the rubber area. Besides, low NR prices have strongly reduced government revenues from export duties.

The need for a more comprehensive analysis regarding the future of the world rubber economy in general and NR's role in it became clear in the middle of the 1970's. Ever since, mere trend extrapolation has shown to be inadequate for forecasting future developments and is therefore an inappropriate tool for assessing the merits of new planting and replanting policies for natural rubber.

1.2 OBJECTIVES OF THIS STUDY

When the author was assigned to United Nations' Economic and Social Commission for Asia and the Pacific (ESCAP) he was requested to do an analysis concerning the future of world rubber demand which should serve as an input for member countries of the Association of Natural Rubber Producing Countries (ANRPC) in determining their production policy. Key factors to be included were such variables as

- economic growth
- oil prices
- saturation level of passenger car usage
- higher mileage of radial tires, and
- reduction in size of passenger cars and consequently of tires in some countries and their possible effects on future rubber demand.

In the final report, projections of rubber demand as well as the underlying assumptions were presented (ESCAP (1978)). Sensitivity of the projections to many key factors was determined as well. Unfortunately the study was done in 1977, at the time when there was broad concensus that the recession in the world economy which started in 1974-1975 had almost come to an end and that the future was bright again. At that time nobody foresaw a second dramatic increase in oil prices and a recession as deep and long as the world economy is experiencing in the early 1980's.

Already in 1979 it became clear that the above study required updating and that results of the study could yet be more useful if they were to be accompanied by an analysis of NR's future role in the world rubber economy. For this purpose a new project was commissioned to the author and the research institute at which he was now working, the Economic and Social Institute of the Free University of Amsterdam, financed from the Netherlands Governments allocation to ESCAP. This study on "Demand and Supply of Natural Rubber" has as its objective
"to assess replanting and new planting policies as well as other aspects of a dynamic production policy for natural rubber and to indicate the policy that optimally meets future demand for natural rubber".

The methodology and techniques of analysis presented in this study have been applied to the most recent data available. However, for certain aspects and for a number of countries, data availability is still very scanty; sometimes too scanty to fully apply the techniques presented here. Therefore, in some cases the approach is more simple than is desirable. For certain other parts of the study, e.g. chapter 9, it would have been extremely useful to have a better insight in the cost structure and the marketing behaviour of the SR industry. The projections of market shares and prices might then be improved upon. It is hoped that such extensions of the analysis could be undertaken in the near future.

1.3 BRIEF REVIEW OF THE MODEL

Locating demand

Basically, the causal sequence underlying aggregate world rubber demand can be described as follows

$$\begin{tikzcd}
E_j \arrow[r] & D_j^k \arrow[r] & T_{ij}^k \arrow[rr, leftrightarrow] \arrow[dr, leftrightarrow] & & Q_i^k \arrow[r] & R_i^k \arrow[r] & \sum\limits_i \sum\limits_k R_i^k \\
& & & Q_j^k \arrow[ur, leftrightarrow] & & &
\end{tikzcd}$$

where

E_j	= exogenous characteristics of country j where the final product is consumed
D_j^k	= demand for end-use k in country j
T_{ij}^k	= net exports of end-use k from country i to country j
Q_i^k	= production of end-use k in country i
R_i^k	= rubber disappearing in end-use k in producing country i
$\sum\limits_i \sum\limits_k R_i^k$	= world rubber demand.

For the *non-tire sector* availability and quality of international trade data are inadequate. Besides, data on D_j^k are hard to obtain. Moreover, the relationship between Q_i^k and R_i^k is very difficult to assess, e.g. how much rubber goes into an average conveyor belt and what is an average conveyor belt. Emphasis, therefore, will lie on R_i^k solely, in relation to industrial production. The causal sequence thus reduces to

$$E_i \longrightarrow R_i^k \longrightarrow \sum_i \sum_k R_i^k$$

where E_i = exogenous characteristics of country i, where the final product is produced, while the other variables are defined above.

In the *tire sector*, E_j differs significantly from country to country. It is very important to include these differences in the model. It is possible to determine D_j^k, but data on T_{ij}^k are inadequate. International trade in tires, be they loose or attached to vehicles, is hard to establish. While emphasis is on the demand structure for tires, rubber demand will be related to the country where the tire is used and not to the country where it is produced. The causal sequence thus becomes

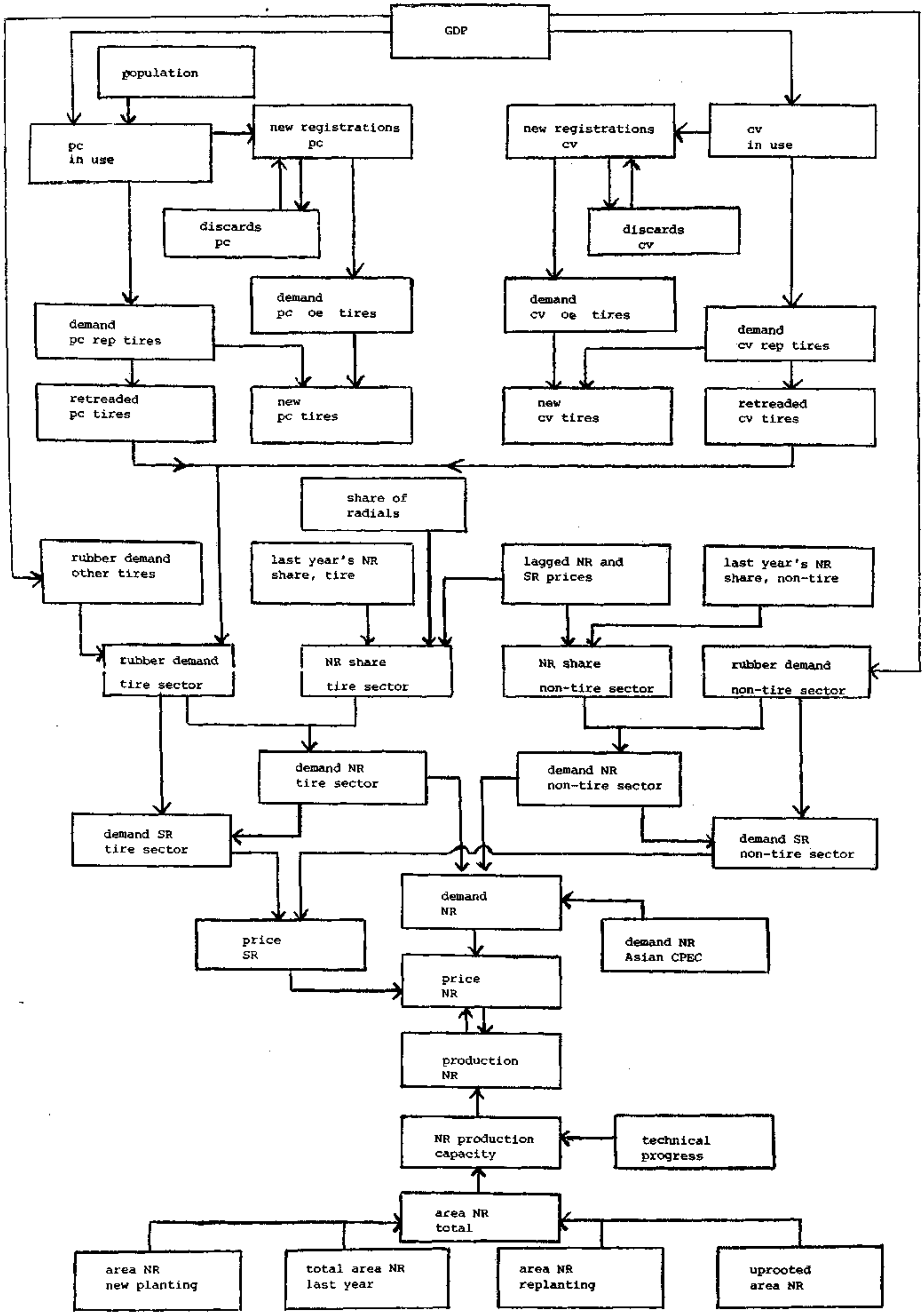
$$E_j \longrightarrow D_j^k \longrightarrow R_j^k \longrightarrow \sum_j \sum_k R_j^k$$

where R_j^k = rubber disappearing in end-use k in consuming country j while the other variables have already been explained. Rubber demand for tires is thus derived by determining the use of tires per country, not by the production of tires per country. Needless to say that only world rubber demand for tires can be established; its factual division amongst countries based on tire production instead of use of tires is not determined.

Schematic review of the model

A schematic representation of the basic relationships underlying the demand-supply situation for natural rubber (NR) and synthetic rubber (SR), is presented in figure 1.1. A verbal description is given in the following chapters. The level of disaggregation of the world into regions may vary between chapters.

Figure 1.1 *The causal tree of the rubber model*



Note: pc = passenger car, cv = commercial vehicle, oe = original equipment, rep = replacement

2. THE PASSENGER CAR MARKET: PASSENGER CARS IN USE

2.1 INTRODUCTION

It is well known that about 60 percent of total rubber usage goes into tires and these tires are attached to vehicles. Because of differences in use of particular types of vehicles and the availability of data, it is expedient to distinguish three categories:

- passenger cars
- commercial vehicles (light, medium and heavy trucks)
- other vehicles.

The latter category consists of such types as motorcycles, bicycles, aeroplanes, earthmovers and other off-the-road vehicles. A striking lack of appropriate data and a low share in world rubber consumption require this category to be treated separately and to be handled in a way which is rather similar to the non-tire sector. This will be discussed in chapter 6.

The two categories, which will be treated more in detail in the following sections and chapters, are passenger cars and commercial vehicles. In developing models and subsequently setting up projections for rubber demand, attention should be focussed on those factors concerning vehicles (passenger cars and commercial vehicles) which determine tire purchase and use. Tires are bought when attached to a new vehicle or to replace tires considered worn-out. Thus, answers must be found to the questions:

- how many vehicles are purchased in order to determine the number of tires for original equipment
- how many vehicles have driven how many kilometres and when will they replace their worn-out tires.

On sales of vehicles, reliable aggregate data are available for a few countries only. A more reliable data series which can represent the same variable is new registrations.

The above considerations lead to a relation between the remaining variables: vehicles in use, new registrations and discards. A newly registered vehicle may be purchased for two reasons: either because a person wants one (more) vehicle, not having one (or enough), or because he wants to replace a vehicle he is already using. The first case represents an increase in the "vehicle park"; the second case requires that the old vehicle be sold to someone wanting to use one (more) vehicle or to replace one he already uses. Replacement (the second case) goes on until the last person in line only has the option of discarding (i.e. scrapping) his old vehicle or adding one more to his existing stock; the net result of the replacement sequence must therefore be discards. If a vehicle is discarded without being replaced, the number of vehicles in use will be reduced. The only problem is international trade in used cars. This is rather minor and does not disturb the picture. Thus, new registrations can be divided into increase in the vehicle park and discards. This fact implies that it is appropriate to explain new registrations using a definitional equation. Behavioural or technical equations must be formulated for discards and for vehicle park. Discards are related to lagged values of new registrations.

The next sections give a presentation of our analysis of the passenger car market, as far as the number of passenger cars in use is concerned. Projections will follow in section 2.3. Discards and new registrations will be discussed in chapter 4.

2.2 HISTORICAL DEVELOPMENTS

Car-ownership is distributed extremely unevenly between countries. Since this study deals with the world as a whole, it will be interesting to obtain some information about this distribution. A list of countries classified by region is shown in table 2.1.

Next to income level, population size is one of the basic explanations underlying the number of cars in use. One has to choose between population size or number of households in order to introduce population aspects into the model. This corresponds to using cars per 1,000 inhabitants or cars per family or household. It has been decided to use the former because

- statistically the number of households or families may be more inaccurate than population size
- it may be hard to make projections about the number of households or families
- the concept of household may be different between countries and may be changing over time.

Levels of car-ownership for every fifth year from 1950 onwards are subsequently presented in table 2.2 as much as possible or relevant on a country level.

Table 2.1 *Countries and regions*

I. North-America

1. United States
2. Canada

II. Asia, developed

3. Japan

III. Oceania, developed

4. Australia
5. New Zealand

IV. North-West Europe

6. Germany F.R.
7. France
8. United Kingdom
9. Netherlands
10. Belgium + Luxemburg
11. Denmark
12. Iceland
13. Sweden
14. Switzerland
15. Ireland
16. Norway
17. Finland
18. Austria

V. South-West Europe

19. Italy
20. Spain
21. Portugal
22. Greece
23. Turkey
24. Yugoslavia
25. Other West Europe

VI. Eastern Europe

26. USSR
27. Czechoslovakia
28. German D.R.
29. Hungary
30. Poland
31. Romania
32. Other Eastern Europe

VII. Latin America + Caribbean

33. Brazil
34. Argentina
35. Mexico
36. Others

VIII. Asia, Centrally Planned

37. China
38. Others

IX. South Asia

39. India
40. Bangladesh
41. Pakistan
42. Sri Lanka
43. Others (Nepal, Burma, Bhutan)

X. South-East + East Asia

44. Indonesia
45. Malaysia
46. Philippines
47. Thailand
48. Singapore
49. Hong Kong
50. Korea
51. Other Oceania
52. Other Asia (excl. Middle East)

XI. Middle East + North Africa

53. Iran
54. Other oil producing + Israel[a]
55. Others[b]

XII. Other Africa

56. Nigeria
57. South Africa
58. Other Africa

Note: a) Algeria, Bahrain, Iraq, Israel, Kuwait, Libya, Oman, Qatar, Saudi Arabia, United Arab Emirates.
b) Cyprus, Egypt, Jordan, Lebanon, Morocco, Spanish Sahara, Syrian Arab Republic, Tunisia, Yemen.

Table 2.2 *Passenger cars in use per 1,000 inhabitants*

	1950	1955	1960	1965	1970	1975	1980[p)]
1. USA	265.4	314.3	341.3	387.6	435.5	499.6	538.5
2. Canada	139.2	186.9	229.3	268.0	310.0	390.7	433.8
3. Japan	0.5	1.7	4.9	22.3	84.7	154.4	203.3
4. Australia	93.4	146.4	196.6	254.0	309.4	363.2	398.0
5. New Zealand	125.3	179.5	215.0	275.4	318.2	376.8	418.0
6. Germany F.R.	12.0	34.6	78.3	152.1	222.6	290.1	376.7
7. France	n.a.	69.7	121.4	196.7	253.9	289.8	353.8
8. United Kingdom	n.a.	71.3	108.1	170.0	215.8	255.2	274.4
9. Netherlands	13.9	24.8	45.4	103.5	173.7	248.1	305.0
10. Belgium + Luxemburg	36.0	54.8	83.2	143.1	215.5	267.6	326.3
11. Denmark	27.6	50.0	88.7	155.2	220.1	254.9	271.5
12. Iceland	42.0	62.0	86.9	147.4	200.0	295.8	373.9
13. Sweden	36.1	87.3	159.2	233.0	286.1	336.6	346.9
14. Switzerland	31.3	54.2	94.3	153.2	223.1	280.3	352.7
15. Ireland	31.0	45.5	62.1	98.3	135.9	166.5	216.5
16. Norway	19.9	35.9	62.5	125.7	191.5	238.5	301.7
17. Finland	6.7	19.8	41.6	98.9	151.5	211.9	256.5
18. Austria	7.4	20.4	57.7	108.4	161.8	229.5	299.2
19. Italy	7.3	18.2	39.7	105.4	189.6	269.9	315.7
20. Spain	3.3	4.5	9.3	25.3	70.6	135.0	197.5
21. Portugal	7.1	11.0	18.0	31.7	65.8	78.5	100.4
22. Greece	1.1	2.5	5.2	12.1	25.7	48.2	91.7
23. Turkey	0.6	1.3	1.7	2.8	3.9	9.9	15.1
24. Yugoslavia	0.4	0.7	2.9	9.7	35.3	71.8	108.8
25. Other Western Europe	n.a.	n.a.	56.6	78.3	130.8	169.7	183.0
26-32. Eastern Europe and USSR	n.a.	n.a.	4.2	7.5	14.5	23.4	41.1
33. Brazil	4.3	6.9	8.8	16.0	25.1	38.7	62.1
34. Argentina	18.5	18.0	23.0	41.2	60.8	88.0	103.2
35. Mexico	6.5	10.0	13.1	17.8	24.5	40.6	51.3
36. Other Latin America + Caribbean	8.6	11.6	13.7	17.5	23.1	28.3[a)]	37.1
37-38. Asia, Centrally Planned	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.

Table 2.2 (continued)

	1950	1955	1960	1965	1970	1975	1980 p)
39. India	0.4	0.5	0.7	0.9	1.1	1.2	1.4
40-43. South Asia, excl. India	n.a.	n.a.	1.7 a)	2.1 a)	2.3 a)	2.4 a)	2.5 a)
44. Indonesia	0.4	0.8	1.1	1.6	2.0	2.8	4.2
45. Malaysia	4.2	8.4	13.2	19.4	26.6	39.4	46.3
46. Philippines	2.1	2.4	3.2	4.3	7.4	8.6	12.6
47. Thailand	0.5	1.1	1.8	2.2	5.2	6.4	9.5
48. Singapore	17.6	32.2	41.0	57.4	70.8	66.3	65.5
49. Hong Kong	5.1	6.8	10.4	15.2	24.6	28.4	36.1
50. Korea	n.a.	0.3	0.5	0.6	1.9	2.4	10.0
53-54. Iran, Other oil producing + Israel	n.a.	n.a.	8.3 a)	12.5 a)	18.5 a)	28.8 a)	33.4 a)
55. Other Middle East + North Africa	n.a.	n.a.	7.4 a)	8.1 a)	9.7 a)	12.2 a)	17.7 a)
56-58. Other Africa	n.a.	n.a.	6.6 a)	7.9 a)	8.9 a)	9.5 a)	9.9 a)

Notes: a) own estimates
p) preliminary

Sources: United Nations' Statistical Yearbook (several issues), Facts and Figures, American Motor Vehicle Manufacturers' Associations (several issues), United Nations, Annual Bulletin of Transport Statistics for Europe (several issues).

Many authors have used this concept of the number of cars per 1,000 inhabitants in studying developments in the number of cars in use. A major part of these studies focusses on the logistic curve. However, it is becoming more and more clear that the properties of the logistic curve, a point of inflexion and two "symmetric parts", are not very realistic.

A graph representing the number of cars per 1,000 inhabitants over time shows the following three phases (figure 2.1).

- an increasingly upward oriented phase ($t < t_1$)
- a linear part ($t_1 < t < t_2$)
- a levelling-off phase ($t > t_2$)

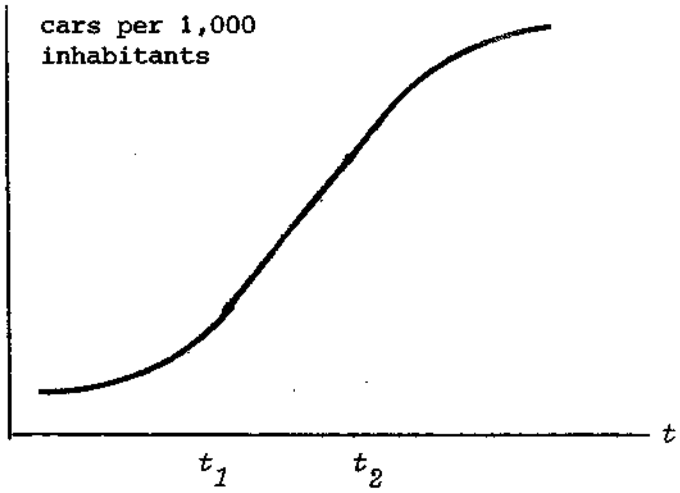


Figure 2.1 *Cars in use per 1,000 inhabitants, the three phases (see text)*

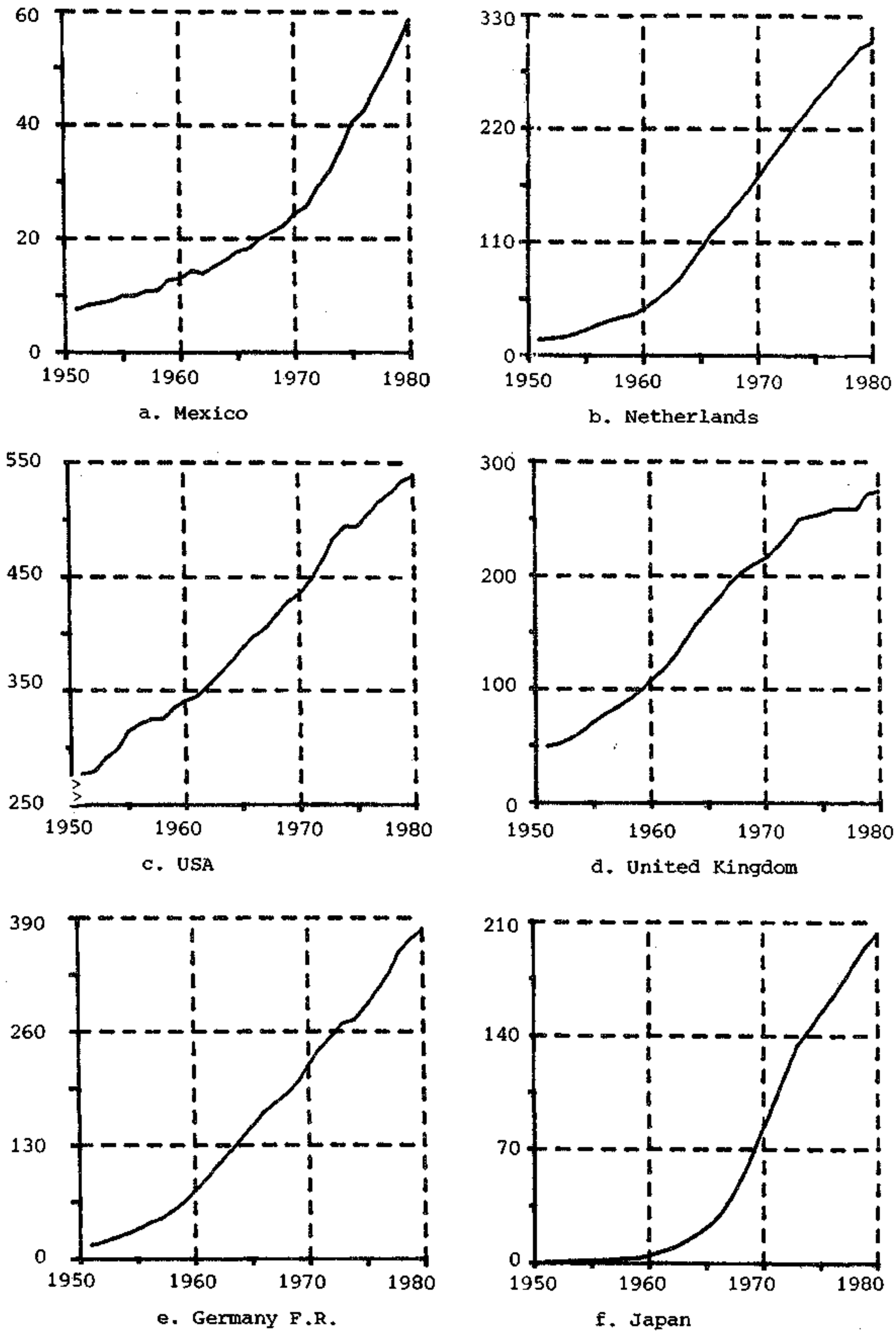
As an illustration of this fact, graphs for a few countries are presented in figure 2.2.

2.3 ANALYSIS AND PROJECTIONS OF PASSENGER CARS IN USE

Analysis of passenger cars in use

In the study a series of conclusions concerning past and perspective developments in car-ownership has been derived. They may be briefly summarized as follows:
- there may be a diffusion process, a learning process, which is rather autonomous over time
- more attractiveness of cars because of changes in prices, supply, quality, etc. is indistinguishable from diffusion aspects
- the diffusion aspect of growth in car-ownership may very well follow a logistic or cumulative normal distribution function of time
- there will be a saturation level, which may differ among countries
- it is better for our purpose to use cars in use per 1,000 persons than per household or family
- at some stage growth in car-ownership will become more income dependent than autonomous
- a change in income growth does not immediately result in a change in passenger cars in use per 1,000 persons; this may be caused by a lag structure.

Figure 2.2 *Passenger cars in use per 1,000 inhabitants, selected countries*



The following approach has been used in the study. Firstly, countries with low levels of cars in use per 1,000 persons need not to be treated with such an elaborate analysis including saturation levels. They are in the first stage of development of car-ownership rates and a simple model will suffice. Secondly, for those countries for which inclusion of a saturation level in the analysis is essential, saturation levels are estimated separately. Relatively small countries such as Malta, Iceland, Kuwait and Lybia have been excluded from the latter group for time-saving purposes. For each of the countries, or, occasionally, groups of countries, the number of cars in use per 1,000 persons is explained from income per capita and autonomous movements.

Determination of saturation levels from time series data was found to be impossible. Therefore another approach had to be devised in order to arrive at a saturation level for each country. Because of differences in demographic, geographic and other characteristics between countries, the saturation level in principle will be different for different countries.

Australia, Austria, Belgium and Luxemburg, Canada, Denmark, Finland, France, Iceland, Ireland, Italy, Japan, Netherlands, New Zealand, Norway, Portugal, Spain, Sweden, Switzerland, United Kingdom, United States and Germany F.R. are the countries included in the saturation-level analysis, being countries with a relatively high level of cars in use per 1,000 persons. In an early stage of the study Greece was included here as well, but was taken out being found to be an outlier in the analysis. Other countries will not come near to saturation in view of very low car-ownership levels at this juncture.

The following aspects could be successfully used while estimating saturation levels per country:
- household size
- population density
- percentage of inhabitable area
- urbanization index
- taxes related to car-ownership
- production of passenger cars.

The analysis then provides saturation levels as ratios to a basic saturation level. For this basis, three possible saturation levels for the USA have been chosen, respectively 600, 650 and 700 cars per 1,000 persons. This leads to three scenarios of (rounded) saturation levels for each of the countries concerned, as presented in table 2.3. Using each of these saturation levels, projections of the number of cars per 1,000 inhabitants will be derived below.

Table 2.3 *Saturation levels for three scenarios, expressed in passenger cars per 1,000 persons*

	Saturation levels		
	Scenario S1	*Scenario S2*	*Scenario S3*
USA	600	650	700
Canada	610	660	710
Japan	320	350	380
Australia	620	680	730
New Zealand	650	700	760
Germany F.R.	470	510	550
France	480	520	560
United Kingdom	480	520	560
Netherlands	350	370	400
Belgium + Luxemburg	390	430	460
Denmark	430	470	500
Iceland	580	630	670
Sweden	430	470	500
Switzerland	400	440	470
Ireland	390	420	460
Norway	470	500	540
Finland	320	350	370
Austria	430	470	510
Italy	440	480	510
Spain	400	430	470
Portugal	390	420	450

Projections of passenger cars in use

In Appendix A economic growth scenarios G1, G2 and G3 for GDP have been detailed and above scenarios for saturation levels S1, S2 and S3 were described. Together with one scenario for population projections, the basis has been laid for projections of passenger cars in use. The energy aspect however - E-scenarios - still has to be fitted in. A description is given in Appendix A as well. The main elements of the passenger car market which are influenced by the energy situation are

- car-ownership, and
- driving distance which possibly affects car life.

The common opinion is that to reduce (growth in) car-ownership, energy availability should become extremely limited. Most people will keep their (aspirations for having a) car but drive less. Driving distance is element of chapter 5 and car life will be discussed in chapter 4. Besides, in some countries some people may switch to smaller cars.

The scenarios for GDP growth and saturation level can now be combined via assumptions about the E-scenarios. Although in theory, with G-, E- and S-scenarios 3 x 2 x 3 = 18 combinations are feasible, their interrelationship makes only some of these combinations practically possible, as is shown in table 2.4.

Table 2.4 *Relationship between G-, E- and S-scenarios*

scenario for		*saturation levels S1*	*S2*	*S3*		*scenario*	*combination of*		
growth	G1	E1	-	-		a	G1	E1	S1
in	G2	E1	E2	-	or	b	G2	E1	S1
GDP	G3	-	E2	E2		c	G2	E2	S2
						d	G3	E2	S2
						e	G3	E2	S3

The third combination: G2, E2 and S2 is called the standard scenario. Projections for passenger cars per 1,000 persons for the standard scenario are presented in detail in table 2.5 . Projections by broad regions for the total number of passenger cars in use are given in table 2.6.

From table 2.5 , it can be concluded that for the standard scenarios, using the assumptions underlying the model, the USA, Canada, Japan, Switzerland, Norway and Finland approach the saturation level by 2000. Many West-European countries show a low growth if any. South-West Asian countries reach dramatic growth rates.

Differences in growth rates of GDP have an enormous impact on projections of passenger cars as can be seen in table 2.6 by comparing economic growth scenarios with the same saturation level, a (low) and b (medium) or c (medium) and d (high), unless saturation levels become important (e.g. North America and Japan).

Table 2.5 *Projections of passenger cars per 1,000 persons for the standard scenario*

	1980	1985	1990	1995	2000
1. USA	539	564	605	631	641
2. Canada	434	492	580	633	651
3. Japan	203	248	309	342	349
4. Australia	398	430	472	518	554
5. New Zealand	418	487	569	627	658
6. Germany F.R.	377	414	453	480	492
7. France	354	363	371	378	383
8. United Kingdom	274	279	282	284	284
9. Netherlands	305	302	302	302	297
10. Belgium + Luxemburg	326	335	344	353	357
11. Denmark	271	278	291	306	319
12. Iceland	374	392	423	444	458
13. Sweden	347	362	388	412	427
14. Switzerland	353	417	437	440	440
15. Ireland	216	243	267	291	310
16. Norway	302	416	484	498	500
17. Finland	256	288	311	329	339
18. Austria	299	338	371	400	415
19. Italy	316	347	368	389	399
20. Spain	197	219	231	239	244
21. Portugal	100	119	149	178	204
22. Greece	92	85	92	94	90
23. Turkey	15	18	25	33	43
24. Yugoslavia	109	140	180	222	265
25. Other Western Europe	183	215	235	244	247
26-32. Eastern Europe and USSR	41	45	53	60	68
33. Brazil	62	67	74	80	86
34. Argentina	103	103	108	112	113
35. Mexico	51	66	90	118	149
36. Other Latin America + Caribbean	37	46	60	75	89
39. India	1	2	2	2	2
40-43. South Asia, excl. India	2	2	3	4	5
44. Indonesia	4	6	7	10	13
45. Malaysia	46	68	101	151	223

Table 2.5 (continued)

	1980	*1985*	*1990*	*1995*	*2000*
46. Philippines	13	19	29	45	68
47. Thailand	10	16	29	51	87
48. Singapore	66	67	69	71	73
49. Hong Kong	36	41	45	48	49
50-52. Korea + Other Asia and Oceania	10	12	15	18	22
53-54. Middle East + North Africa, oil producing	33	35	39	43	46
55. Other Middle East + North Africa	18	21	26	31	37
56-58. Other Africa	10	12	14	16	18

Table 2.6 *Projections of passenger cars in use by broad regions, for 5 scenarios (see text), in thousands*

	scenario	*1980*	*1985*	*1990*	*1995*	*2000*
I. North America	a	132,975	144,039	155,771	166,969	175,833
	b		146,597	162,744	174,655	183,529
	c		148,236	168,997	185,390	196,903
	d		151,473	175,979	190,056	199,338
	e		152,136	182,172	201,979	213,903
II. Asia, developed	a	23,927	29,995	35,796	39,187	40,496
	b		30,988	37,766	40,039	40,726
	c		29,857	38,176	42,980	44,428
	d		30,805	40,476	43,778	44,549
	e		31,109	42,807	47,402	48,362
III. Oceania, developed	a	7,118	8,120	9,012	9,793	10,388
	b		8,255	9,655	11,049	12,226
	c		8,243	9,672	11,165	12,490
	d		8,381	10,384	12,494	14,125
	e		8,395	10,516	12,908	14,857
IV. North-West Europe	a	77,232	81,092	82,671	83,877	84,256
	b		82,408	86,886	90,018	91,657
	c		82,833	88,019	91,899	94,013
	d		84,170	91,955	97,139	100,057
	e		84,474	93,471	99,931	103,538
V. South-West Europe	a	30,487	34,376	36,771	38,810	40,306
	b		35,082	39,469	43,836	47,674
	c		35,117	39,515	43,909	47,704
	d		36,152	43,475	50,916	58,112
	e		36,228	43,862	51,832	59,399

Table 2.6 (continued)

	scenario	1980	1985	1990	1995	2000
VI. Eastern Europe	a	15,532	17,031	19,177	21,443	23,452
	b		17,717	21,305	25,035	28,742
	c		17,717	21,305	25,035	28,742
	d		18,459	23,738	29,352	35,404
	e		18,459	23,738	29,352	35,404
VII. Latin America + Caribbean	a	19,352	23,674	29,720	36,391	43,142
	b		25,268	34,913	47,036	61,575
	c		25,268	34,913	47,036	61,575
	d		27,297	42,268	63,939	94,610
	e		27,297	42,268	63,939	94,610
IX. South Asia	a	1,335	1,683	2,135	2,631	3,140
	b		1,755	2,359	3,042	3,790
	c		1,755	2,359	3,042	3,790
	d		1,837	2,626	3,552	4,632
	e		1,837	2,626	3,552	4,632
X. South-East + East Asia	a	3,257	4,861	7,463	11,469	17,584
	b		5,026	8,076	13,001	20,885
	c		5,026	8,076	13,001	20,885
	d		5,204	8,758	14,799	24,974
	e		5,204	8,758	14,799	24,974
XI. Middle East + North Africa	a	4,538	5,424	6,635	7,996	9,484
	b		5,693	7,509	9,680	12,204
	c		5,693	7,509	9,680	12,204
	d		6,002	8,587	11,935	16,145
	e		6,002	8,587	11,935	16,145
XII. Other Africa	a	4,341	5,900	7,937	10,479	13,609
	b		5,991	8,213	10,994	14,448
	c		5,991	8,213	10,994	14,448
	d		6,103	8,564	11,678	15,608
	e		6,103	8,564	11,678	15,608
World excl. Asian Centrally Planned Economies	a	320,100	356,201	393,093	429,050	461,696
	b		364,784	418,900	468,390	517,462
	c		365,740	426,759	484,137	537,186
	d		375,887	456,816	529,645	607,560
	e		377,249	467,375	549,312	631,439

3. THE COMMERCIAL VEHICLE MARKET: COMMERCIAL VEHICLES IN USE

3.1 INTRODUCTION

When developing models and subsequently setting up projections for rubber demand, attention should be focussed on those factors concerning commercial vehicles which determine tire purchase and use. Tires are bought as attached to a new vehicle or as replacement for worn-out tires. Thus, emphasis must be placed on:

- how many new vehicles are purchased in order to determine the number of tires for original equipment
- how many vehicles have driven how many kilometres and when will their tires be considered worn-out.

The conclusions from the remarks about the passenger car statistics in section 2.1 are as relevant for commercial vehicles as they are for passenger cars.

This brings us to the three important variables: commercial vehicles in use, new registrations and discards. New registrations can again be divided into increase in the vehicle park and discards. Discards can be related to lagged values of new registrations where lag parameters may be influenced by developments in income.

3.2 HISTORICAL DEVELOPMENTS

Usage of commercial vehicles is distributed extremely unevenly between countries. Obvious reasons for this phenomenon are size of the economy and level of economic activity. Some information on ownership of commercial vehicles is shown in table 3.1. Countries are listed as in table 2.1.

An immediate feature of this table is the pronounced share of the USA in the world vehicle stock, although its share is declining from about 55 percent in the early fifties to about 40 percent in the late seventies. The second most important country, as far as commercial vehicle-ownership in 1975 is concerned, is Japan. Its development in the last decades to one of the leading industrial nations has been accompanied by a huge increase in its commercial vehicle park. Growth rates are 18.6 % annually in the 1950's and 20.2 % in the 1960's.

Table 3.1 *Commercial vehicles in use (in thousands)*

	1950	*1955*	*1960*	*1965*	*1970*	*1975*	*1980*[p]
1. USA	8,828	10,558	12,210	15,015	19,127	26,243	35,562
2. Canada	650	977	1,117	1,345	1,738	2,543	3,045
3. Japan	251	710	1,383	4,298	8,740	10,815	15,870
4. Australia	499	650	838	874	972	1,200	1,469
5. New Zealand	82	115	125	159	182	206	255
6. Germany F.R.	552	635	728	865	1,002	1,341	1,550
7. France	406	662	909	1,213	1,615	2,134	2,615
8. United Kingdom	n.a.	1,208	1,519	1,791	1,754	1,911	2,001
9-10. Benelux	230	252	362	482	573	647	679
11. Denmark	61	103	170	244	257	239	276
12. Iceland	4	5	6	6	6	7	8
13. Sweden	86	108	115	141	159	171	199
14. Switzerland	40	54	61	93	141	179	194
15. Ireland	27	42	46	51	53	58	66
16. Norway	52	85	113	132	152	147	189
17. Finland	33	55	73	88	111	137	157
18. Austria	16	41	69	101	138	151	197
19. Italy	229	367	459	666	930	1,140	1,229
20. Spain	83	102	149	387	741	1,040	1,378
21. Portugal	29	40	50	89	132	193	257
22. Greece	21	27	37	73	117	211	399
23. Turkey	19	41	68	101	160	271	398
24. Yugoslavia	6	13	39	67	122	179	394
25. Other W. Europe	n.a.	n.a.	5	7	11	13	18
26-32. Eastern Europe + USSR	n.a.	n.a.	3,520	4,220	5,270	6,150	9,200
33. Brazil	100	181	335	517	696	1,063	2,025
34. Argentina	239	260	390	571	755	874	1,250
35. Mexico	130	242	315	389	589	888	1,604
36. Other Latin America	325	563	644	898	n.a.	n.a.	1,950
37-38. Asia,Centr.Pl.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
39. India	113	157	246	376	414	434	530
40-43. S.Asia,excl.India	n.a.	n.a.	176[a]	234[a]	284[a]	332[a]	424
41. Pakistan	14	20	30	45	64	70	100
42. Sri Lanka	14	22	31	36	45	49	68
44. Indonesia	29	55	92	103	126	232	450
45. Malaysia	15	22	34	52	73	114	145
46. Philippines	55	63	75	130	179	272	500
47. Thailand	13	28	50	76	163	234	390
48. Singapore	7	11	15	23	38	46	70
49. Hong Kong	4	4	10	20	29	44	60
50. Korea	n.a.	11	19	25	65	100	250
53. Iran	18	24	44	48	74	189	200
53-54. Oil producing Arab. + Israel	n.a.	n.a.	152[a]	250[a]	411[a]	711[a]	1,550
55. Other ME + NA	n.a.	n.a.	212[a]	250[a]	314[a]	411[a]	1,010
56. Nigeria	n.a.	n.a.	20	26	40	86	300
57. South Africa	112	146	198	315	428	800	900
56-58. Other Africa	n.a.	n.a.	675[a]	975[a]	1,434[a]	1,836[a]	2,200[a]

Note: a) own estimates Source: as for table 2.2.
p) preliminary

Most countries, however, show average growth rates between 1950 and 1975 ranging from 3.5 to 6.0 %. Apart from Japan, countries with more than 6.0 % growth in commercial vehicle park are France, Austria, most South-European countries and most developing countries. Countries with a lower level of growth than 3.5 % are Sweden, the United Kingdom and Ireland.

There might be a relationship between the number of commercial vehicles in use and GDP. Scatter-diagrams, as analyzed in the study, illustrate this. Most of the countries show a rather straightforward relationship between commercial vehicles in use and total GDP. The reaction to the oil crisis is very interesting. Five patterns can be distinguished:

a) negative or low growth in GDP and hardly any change in the pattern of the number of commercial vehicles in use, cf. United States;
b) hardly any growth, both in GDP and the number of commercial vehicles in use, cf. Japan;
c) no change in pattern of development both in GDP and commercial vehicles in use, cf. Australia;
d) slight reduction in the number of commercial vehicles while the pattern of GDP growth has not really changed, cf. Italy;
e) rather hectic developments, from which no substantial conclusion can be drawn, cf. United Kingdom and Norway.

3.3 ANALYSIS AND PROJECTIONS OF COMMERCIAL VEHICLES IN USE

Analysis of commercial vehicles in use

The number of studies on this subject is remarkably smaller than in the case of passenger cars. Presumably the reasons for this are less accessible data and more complex reality. The important variables are:

- commercial vehicles in use
- annual road transportation in ton-kilometre
- average capacity of vehicles
- average degree of capacity utilization
- average annual mileage.

The main problem is the data base. Data on the number of commercial vehicles in use are available and are of reasonable quality, although some modifications have had to be introduced. Figures on road transportation are readily available for a few countries only. Even more difficult to obtain is reliable information for most countries on the variables. With regard to loading capacity, some statistics for some countries are available. For almost all countries of the world, data on capacity utilization and average driving distance are too scarce to permit any time series analysis. In other cases they do not vary over time. All this means that there is no proper basis for an analysis of the relationship between commercial vehicles in use and road transportation. On the other hand, road transportation is related to the volume of over-all production, in this case represented by GDP. Taking all these aspects into account it has been decided to relate the number of vehicles in use directly to GDP.

For projections, similar to the case of passenger cars, calculations are based on the scenarios for GDP as have been drawn up in Appendix A, without separately paying attention to energy aspects for the reasons mentioned above. Projection results for the three economic scenarios are summarized for broad regions in table 3.2. Differences in economic growth scenarios have an enormous impact on future numbers of commercial vehicles in use, as can be seen in table 3.2 by comparing the three scenarios. This especially is the case for North-America, Japan and Africa.

Table 3.2 *Projections of commercial vehicles in use (in thousands) for 3 economic scenarios*

	scenario	*1980*	*1985*	*1990*	*1995*	*2000*
I. North-America	G1	38,550	42,054	47,498	51,991	55,212
	G2		44,892	55,190	65,587	75,535
	G3		47,843	63,777	81,893	101,732
II. Asia, developed	G1	14,281	17,527	21,920	26,550	31,217
	G2		18,728	25,321	33,077	41,897
	G3		19,982	29,133	40,933	55,708
III. Oceania, developed	G1	1,706	1,845	1,938	2,007	2,054
	G2		1,877	2,067	2,268	2,453
	G3		1,909	2,206	2,566	2,938
IV. North-West Europe	G1	7,990	8,091	8,312	8,464	8,534
	G2		8,333	9,003	9,598	10,035
	G3		8,658	9,966	11,268	12,375
V. South-West Europe	G1	4,041	4,267	4,674	5,099	5,480
	G2		4,399	5,120	5,958	6,804
	G3		4,560	5,683	7,083	8,611
VI. Eastern Europe	G1	8,811	9,597	10,461	11,339	12,187
	G2		9,679	10,716	11,770	12,821
	G3		9,768	11,008	12,288	13,621
VII. Latin America + Caribbean	G1	6,662	7,747	8,791	9,917	11,075
	G2		7,901	9,324	10,961	12,751
	G3		8,100	10,070	12,511	15,387
IX. South Asia	G1	944	1,061	1,214	1,381	1,537
	G2		1,100	1,341	1,600	1,871
	G3		1,151	1,508	1,906	2,356
X. South-East + East Asia	G1	2,205	2,870	3,780	4,909	6,285
	G2		2,987	4,160	5,722	7,748
	G3		3,108	4,580	6,673	9,564
XI. Middle East + North Africa	G1	2,536	3,527	4,872	6,612	8,687
	G2		3,710	5,551	7,937	10,951
	G3		3,903	6,314	9,498	13,751
XII. Other Africa	G1	2,198	2,649	3,314	4,098	4,981
	G2		2,807	3,797	5,001	6,451
	G3		3,004	4,412	6,200	8,483
World totals	G1	89,929	101,241	116,779	132,374	147,255
	G2		106,419	131,597	159,485	189,323
	G3		111,993	148,662	192,825	244,532

4. DISCARDS AND NEW REGISTRATIONS OF VEHICLES

4.1 INTRODUCTION

In chapter 1, the Introduction, it was stated that, for the purpose of deriving projections of rubber demand, it is necessary to analyze the vehicle market, both for passenger cars and commercial vehicles. In the introductions to chapters 2 and 3, the role of various aspects of the vehicle market in determining tire demand and thus part of rubber demand has been elaborated upon.

It has been concluded that it is necessary to know and make projections of the number of vehicles in use. These are the determinants for the numbers of tires required for replacement of worn-out tires. Next to this, one needs to know the number of new vehicles being produced because this is where tires for original equipment come to the fore. Because of quality of data, new registrations rather than production data have been used. It is hoped that discrepancies because of lags and abnormal inventory levels will have little significance in the long run. These new registrations may function as replacement of vehicles or extension of the vehicle park.

While extension of the vehicle park has been discussed in chapters 2 and 3, in this chapter emphasis will be on discards and new registration of vehicles.

During the course of the study, it was concluded, that owing to short- and long-term changes, average life of vehicle should rather not be assumed constant. Many factors may influence average vehicle life:

- economic development, particularly in income
- driving distance
- safety regulations
- quality of roads
- driving style
- repair costs versus cost of buying a new vehicle
- quality of cars, regarding maintenance

- quality of vehicles, concerning construction.

This implies that average life should be treated as a variable rather than a parameter both with respect to model construction and forecasting.

Should all the above factors be included in the analysis? It is impossible to do so because of data limitations and the resulting complicated analysis. It would be easier to assume that average life of vehicles should be different for different vintages τ (construction years) and for different years of usage t. Average life per vintage τ and per year t might therefore be indicated with $\mu_{t\tau}$. Since no data on $\mu_{t\tau}$ are available, one has to estimate these data on the basis of such variables as new registrations, discards and number of vehicles in use. It has not been feasible to arrive at such a two dimensional variable $\mu_{t\tau}$ for each country. While having to choose between an analysis based on μ_{τ}, a vintage determined average life, or on μ_t, a usage year fixed average life, one has to find out which aspects are more important: the quality of the car (technical and age) or the quality of the economy (economic and age). Particular in view of recent developments in discarding of cars where replacement is postponed because of the economic recession, it has been decided to concentrate on the disembodied sides of $\mu_{t\tau}$ only and therefore to base the analysis on μ_t.

Attention will therefore be paid to year to year developments in aggregate average vehicle life μ_t. A method has been developed to estimate μ_t for each year in the sample period, because data on μ_t are not available. In 4.2, estimates of μ_t for passenger cars for various countries will be made. Projections of μ_t, discards and new registrations of passenger cars will be presented in section 4.3. In 4.4 and 4.5 similar results for commercial vehicles will be given.

4.2 ESTIMATION OF AVERAGE LIFE OF PASSENGER CARS

Estimation results for the USA

The above indicated model has been applied for the USA for the period 1959-1980. The starting year s is 1959. So μ_t is derived for 1960-1980. Some data as well as results on μ_s for 1959 and μ_t for t = 1960, ..., 1980 are given in table 4.1.

Estimation results for other countries or regions

Estimation of average car life requires data on new registrations which are of reasonable quality and of a reasonable level during at least 12 to 18 years before the beginning of the estimation period. For many regions, therefore, the estimation period for μ_t could only be 1968-1980 while s = 1967 = the initial year. For some countries, reasonably accurate estimates can only be obtained for a shorter period e.g. Japan and France. Results for 1980 are presented in table 4.2.

Table 4.1 *New registrations and discards (in thousands) and estimated average life in years of passenger cars in the USA*

	New registrations	*Discards*	*Estimated average life*
1959	6,041	3,350	10.94
1960	6,577	4,468	10.69
1961	5,855	4,105	11.25
1962	6,939	4,275	11.41
1963	7,557	4,604	11.41
1964	8,065	5,108	11.25
1965	9,314	6,051	10.77
1966	9,008	6,141	10.72
1967	8,357	6,083	10.75
1968	9,404	6,198	10.68
1969	9,446	6,193	10.70
1970	8,388	6,002	10.88
1971	9,831	6,357	10.82
1972	10,488	6,124	11.11
1973	11,351	6,448	11.16
1974	8,410	5,539	11.95
1975	8,262	6,399	11.79
1976	9,752	6,282	12.16
1977	10,826	7,319	11.93
1978	10,946	8,304	11.69
1979	10,357	7,264	12.36
1980	8,761	6,414	13.08

For many countries, such as the United States, Canada and Germany average life tends to increase over time. Other countries, e.g. North-West Europe I, show a decrease, which may be caused by safety regulations and smaller cars. Other countries do not show significant downward or upward movements. It is not clear in many cases whether the 1973-1974 oil crisis had an impact on average life of passenger cars. However, the estimates for 1980, in general, are higher than those for 1979. This may be explained by such factors as the oil price increase in 1979 and the economic recession. The results would seem rather robust as regards the difference in average life between countries. High values are obtained for Italy, USA, Canada and, somewhat lower, for North-West Europe II. Estimated average car life in recent years comes close to or around 10 years in the larger countries of Western Europe. The small relatively wealthy countries of Europe grouped in North-West Europe I show a much lower level of about 9 years, which is rather similar to the case of Japan.

4.3 PROJECTIONS OF AVERAGE LIFE, DISCARDS AND NEW REGISTRATIONS OF PASSENGER CARS

In the previous section results of a method to estimate average life of passenger cars have been discussed. The vintage approach offered good results particularly because of possible changes in average life over time. In this section projections of discards and new registrations will be made, based on projections of average life.

Projections of average life

It has been concluded in the study that income scenarios have very little influence on average life. Therefore projections on average life of passenger cars have been made based on the following assumptions. For the relatively rich countries and regions for which the vintage approach has been used, the estimate for 1980 may be a maximum and a slight decrease might be foreseen owing to economic recovery. For the other regions estimated car life has been derived using a constant lag approach and is assumed constant for the future. Projections of average car life are given in table 4.2.

Table 4.2 *Projections of average life for passenger cars*

	1980	1985	1990	1995	2000
1. USA	13.00	12.75	12.50	12.25	12.00
2. Canada	12.60	12.35	12.10	11.85	11.60
3. Japan	9.30	9.05	8.80	8.55	8.30
4-5. Australia + New Zealand	14.00	13.50	13.00	12.50	12.00
6. Germany F.R.	9.60	9.35	9.10	8.85	8.60
7. France	10.30	10.05	9.80	9.55	9.30
8. United Kingdom	9.60	9.35	9.10	8.85	8.60
9-14. North-West Europe I	9.00	8.75	8.50	8.25	8.00
15-18. North-West Europe II	12.40	12.15	11.90	11.65	11.40
19. Italy	15.00	14.75	14.50	14.25	14.00
20-25. Southern Europe	13.60	13.60	13.60	13.60	13.60
26-32. Eastern Europe	14.00	14.00	14.00	14.00	14.00
33-36. Latin America	14.50	14.50	14.50	14.50	14.50
39-43. South Asia	16.00	16.00	16.00	16.00	16.00
44-52. East + South-East Asia	14.50	14.50	14.50	14.50	14.50
53-54. Middle East + North Africa (oil)	12.00	12.00	12.00	12.00	12.00
55-58. Other Middle East + Africa	15.00	15.00	15.00	15.00	15.00

Projections of discards and new registrations of passenger cars

All required elements have been described in this and the previous chapters. Basis for the projections of discards and new registrations is the series of projections of cars in use for 5 combinations of saturation- and economic growth scenarios from chapter 2. In order to reduce the number of tables only projections of new registrations for 5 scenarios for passenger cars in use are presented in table 4.3.

It is interesting to note that until 1990 discards will hardly be influenced by the economic scenario, the reason being that these discards are based on new registrations around 1980, which are either data or hardly influenced by scenario differences. Especially for the USA, which showed a dramatic drop in new registrations in the early 1980's and which has a rather high projected average life for passenger cars, discards in 1995 are hardly higher than in 1990, particularly for the low growth scenario.

Table 4.3 *Projections of new registrations of passenger cars (in thousands) for 5 scenarios (see text)*

	scenario	*1980*	*1985*	*1990*	*1995*	*2000*
I. North-America	a	9,693	10,607	13,032	12,894	13,596
	b		11,769	13,789	13,260	14,262
	c		11,961	14,770	14,206	15,211
	d		12,914	14,966	14,064	15,421
	e		13,172	16,152	15,172	16,484
II. Asia, developed	a	2,805	3,810	4,370	4,486	4,722
	b		4,124	4,337	4,523	4,699
	c		4,096	4,965	4,882	5,222
	d		4,411	4,873	4,936	5,187
	e		4,589	5,409	5,297	5,656
III. Oceania, developed	a	533	746	870	934	1,011
	b		817	969	950	1,047
	c		823	1,042	1,054	1,132
	d		894	1,110	1,024	1,148
	e		908	1,196	1,115	1,223
IV. North-West Europe	a	7,828	8,681	9,381	9,747	10,155
	b		8,971	9,605	10,113	10,551
	c		9,373	10,028	10,673	11,187
	d		9,688	10,173	11,010	11,511
	e		10,151	10,606	11,618	12,183
V. South-West Europe	a	2,516	2,884	3,400	3,544	3,851
	b		3,171	3,745	3,911	4,510
	c		3,238	3,966	4,069	4,653
	d		3,539	4,198	4,424	5,411
	e		3,602	4,405	4,545	5,545
VI. Eastern Europe	a	1,038	1,515	2,017	2,279	2,712
	b		1,715	2,466	3,031	3,888
	c		1,715	2,466	3,031	3,888
	d		1,922	2,827	3,681	4,956
	e		1,922	2,827	3,681	4,956
VII. Latin America + Caribbean	a	1,301	1,928	2,920	3,938	5,219
	b		2,338	4,048	6,240	9,519
	c		2,338	4,048	6,240	9,519
	d		2,788	5,095	8,661	14,576
	e		2,788	5,095	8,661	14,576
IX. South Asia	a	188	233	300	396	489
	b		258	362	502	664
	c		258	362	502	664
	d		284	411	593	823
	e		284	411	593	823

Table 4.3 (continued)

	scenario	*1980*	*1985*	*1990*	*1995*	*2000*
X. South-East + East Asia	a	343	541	899	1,445	2,266
	b		590	1,056	1,808	3,042
	c		590	1,056	1,808	3,042
	d		640	1,184	2,124	3,757
	e		640	1,184	2,124	3,757
XI. Middle East + North Africa	a	233	391	499	561	689
	b		455	652	835	1,122
	c		455	652	835	1,122
	d		505	778	1,083	1,549
	e		505	778	1,083	1,549
XII. Other Africa	a	533	703	903	1,167	1,456
	b		736	975	1,283	1,633
	c		736	975	1,283	1,633
	d		771	1,033	1,382	1,805
	e		771	1,033	1,382	1,805

Turning to new registrations, being equal to discards plus change in the number of cars in use, of course, patterns will reflect patterns in discards. For the low growth and the standard scenarios in particular, there will be no increase in new registrations in the 1990's in most developed countries. The growth market will be in regions like Latin America and Asia and to a lesser extent in Africa.

4.4 ESTIMATION OF AVERAGE LIFE FOR COMMERCIAL VEHICLES

As in the case of passenger cars, the vintage approach may be used to derive estimates of average life which then may vary over time. The same method for adjustment has been applied. Since information about recent years is most important, estimates of average life have been derived from 1975 onwards. They are presented for 1981 in table 4.4.

4.5 PROJECTIONS OF AVERAGE LIFE, DISCARDS AND NEW REGISTRATIONS OF COMMERCIAL VEHICLES

For projection purposes average life will be assumed as summarized in table 4.4. Similar to the case of passenger cars, projections of discards can be made on the basis of vintages or, if data are not adequately available (countries 15-58), on the basis of distributed lags using a normal probability distribution. Starting from projections on commercial vehicles in use, as described in chapter 3 for three economic growth scenarios, projections of discards and new registrations can be made.

Table 4.4 *Projected average life of commercial vehicles*

		1981	*change per year*
1.	USA	15.0	-0.1
2.	Canada	9.5	0
3.	Japan	13.0	-0.05
4-5.	Australia + New Zealand	13.5	-0.05
6.	Germany F.R.	11.8	0
7.	France	8.4	+0.05
8.	United Kingdom	7.7	+0.05
9-14.	North-West Europe I	9.8	0
15-18.	North-West Europe II	10.5	0
19.	Italy	11.5	0
20-25.	Southern Europe	11.5	0
26-32.	Eastern Europe	13.5	0
33-36.	Latin America	15.0	0
39-43.	South Asia	17.0	0
44-52.	East + South-East Asia	16.0	0
53-54.	Middle East + North Africa (oil)	13.0	0
55-58.	Other Middle East + Africa	16.0	0

In table 4.5 projections of new registrations for three scenarios are summarized by broad regions.

As in the case of passenger cars, until 1990 discards of commercial vehicles are hardly influenced by the economic scenario, because they are largely based on data on vehicles in use before 1982. Extension of the vehicle park during the 1980's, being strongly influenced by economic growth scenarios, has an important effect on discards in the 1990's. The high level of average life in 1980 caused by postponement of discarding in such regions as North America and developed Asia, and the assumed small decrease in average life in the 1980's, creates a strong growth in discards in the 1980's, thus also compensating postponement in the years around 1980.

Development in new registrations are only partly a reflection of discards. The absence of significant growth in the vehicle park in most regions results in low or even negative growth in new registrations. This is particularly true for Oceania, Europe, Latin America and South Asia. Growth prospects are bright for North America, East Asia and Africa.

Table 4.5 *Projections of new registrations of commercial vehicles (in thousands) for three scenarios (see text)*

	scenario	*1980*	*1985*	*1990*	*1995*	*2000*
I. North-America	G1	2,809	3,093	4,461	4,668	4,678
	G2		3,922	5,594	6,308	7,028
	G3		4,814	6,960	8,441	10,278
II. Asia, developed	G1	1,109	1,643	2,181	2,532	2,973
	G2		1,983	2,731	3,449	4,365
	G3		2,351	3,391	4,628	6,287
III. Oceania, developed	G1	142	141	163	166	166
	G2		153	187	195	211
	G3		166	214	237	270
IV. North-West Europe	G1	965	852	911	889	875
	G2		928	1,027	1,048	1,055
	G3		1,030	1,197	1,298	1,354
V. South-West Europe	G1	473	349	479	457	509
	G2		395	556	579	675
	G3		452	656	744	910
VI. Eastern Europe	G1	1,102	887	1,108	1,098	1,137
	G2		909	1,149	1,149	1,210
	G3		934	1,197	1,212	1,305
VII. Latin America + Caribbean	G1	702	541	740	874	863
	G2		593	831	1,002	1,052
	G3		663	967	1,205	1,368
IX. South Asia	G1	83	73	87	84	90
	G2		85	106	107	123
	G3		100	133	141	174
X. Sout-East + East Asia	G1	404	230	380	501	577
	G2		266	446	614	761
	G3		304	522	755	1,004
XI. Middle East + North Africa	G1	129	110	187	166	174
	G2		125	209	202	225
	G3		143	238	251	299
XII. Other Africa	G1	399	450	615	838	1,063
	G2		535	792	1,080	1,457
	G3		634	1,010	1,396	1,987

5. DEMAND FOR TIRES FOR PASSENGER CARS AND COMMERCIAL VEHICLES

5.1 INTRODUCTION

In chapters 2, 3 and 4 projections were derived of the number of vehicles in use, new registrations and discards of vehicles both for passenger cars and commercial vehicles. This detailed analysis of the basic indicators of the size and the growth of the vehicle park was necessary in order to determine the demand for tires in the country where the tires are used as was already indicated in chapter 1, section 1.2. It has also been pointed out previously, that new registrations of vehicles can be used as the variable determining the demand for tires for original equipment. The demand for tires for tire replacement purposes, however, is determined by vehicles in use minus that year's discards, since it is assumed that tire replacement will not take place just prior before discarding of the vehicle. After some background information about properties of and types of tires (sections 5.2), the method of deriving demand for tires will be presented: original equipment (OE) tires in section 5.3 and replacement (RP) tires in section 5.4.

5.2 TYPES AND PROPERTIES OF TIRES

Conventional versus radial tires

The past two decades have shown dramatic changes in the tire scene. In the early sixties virtually the only type of tires were the cross-ply tires. Then the radial tire started conquering the market in Europe. First there was the textile belted radial tire; more recently the steel belted radial has become increasingly important. In the USA meanwhile the bias belted tire had become popular, both with glass and steel belts. In Japan, the move to radial gathered momentum in the seventies as well. There may be some bias in these kind of figures because of international trade in new vehicles.

Advantages of using radial tires

What are the advantages of the radial tire compared to the conventional cross-ply or bias belted tire? The most important aspect is tire distance defined as the number of kilometres over which the (set of) tires can last from the start until replacement. Radial tire distance will reach some 50 to 100 percent more than that of conventional cross-ply tires, while bias belted tires are somewhere in between. High capital investments in bias belted plants in the USA after World War II and the higher tire distance of bias belted tires compared to other conventional tires were reasons behind postponement of penetration of the radial tire in the USA.

Further advantages of radial tires are in the area of cooler running, better tread wear and better road holding under most conditions. One of the most important factors is better rolling resistance, thus reducing energy consumption for driving. For further information see Vila (1972), Bottasso (1980), Buckler et al. (1980), Kaneko (1980), Kovac and Ambelang (1980) and Alexander (1981).

Elastomer composition

A further impact of the switch from conventional to radial tires is the composition of the rubber content: the content of natural rubber (NR) and polyisoprene rubber (IR) increases dramatically to the detriment of styrene butadiene rubber (SBR). This applies both to passenger car- and to truck tires. NR is used in the sidewalls of the tires and is required for technical purposes particularly in the area of obtaining complete adhesion at the interface of the steelcord and the rubber parts, in view of the high stress concentration that can develop there (cf. Buckler et al. (1980), Bottasso (1980), Kaneko (1980)).

One of the targets which may receive further priority in the years ahead is lowering the rolling resistance in order to reduce fuel consumption. In this respect NR has an advantage, so that NR can take an even larger share of the rubber content of passenger car tires (cf. Bottasso (1980)).

Tire distance and replacement

How long does a car tire last? It is impossible to answer this question because tire distance depends on a large variety of factors such as:
- the type of tire: cross-ply, bias-belted, textile radial, steel radial
- commercial vehicle tubeless radial tires which last longer than tubed radial tires
- the size of the tire in relation to the size of the car or the commercial vehicle
- front wheel drive which may reduce tire distance of the front wheel tires by some 20 percent
- heavy loads reduce tire life
- road quality
- traffic conditions
- driving style
- speed limits
- safety regulations.

It will be clear that only an estimate of average life can be derived; moreover this estimate may change over time, and ought to be disaggregated between conventional and radial tires. Some estimates have been made in a recent article by Allen (1980). He arrives at estimates of radial-ply tire distance of 46,000 km for the United Kingdom, 50,000 km for Germany F.R. and 56,000 km for the USA. This is roughly twice the tire distance of conventional tires. A shift from textile radials to steelcord reinforced radials may provide another increase in tire distance of about 6,000 km. In section 5.4 our own results will be presented.

If the worn-out tire is not damaged the tread may be replaced (retreaded, remoulded, recovered). Thus, a reduction in usage of commodities and energy is attained. Retreading the same carcass can only be done once or twice. A prerequisite is that the old tread has not fully disappeared. There may be technical difficulties in retreading tires, especially lower quality tires. Although technological improvements have been considerable over the past decades, there is still concern by users about safety of tires after retreading. Another impediment to further penetration of retreaded tires is the price of certain qualities of new tires, compared to retreaded tires, particularly in case of imports of very cheap tires in some countries. A retreaded tire will have a slightly lower tire distance compared to a new tire.

In case of truck tires with a thick tread, it may be possible to apply the techniques of regrooving: an extra 2-3 mm is cut out after part of the tread has disappeared. This may extend tire distance by another 50 to 100 percent.

5.3 TIRES FOR ORIGINAL EQUIPMENT

Passenger cars

First, passenger car tires will be discussed. Nobody will question the statement that over 99.9 percent of passenger cars nowadays are driving around on four wheels, and it does not seem likely that this will change in the near future. Of major importance is the presence of the spare tire, which means that virtually all new cars are equipped with five tires. However, newly developed tires (so-called safety tires or run-flat tires) scheduled to be introduced in the near future may have an impact on this variable because of their ability to cover a considerable distance after puncture. Owing to the chemical composition of these tires, little or no manoeuvrability is lost after being punctured and therefore the danger of an accident is enormously reduced. The share of this new system of tires may increase over time depending on the country. This phenomenon would then reduce the average number of tires per new passenger car. On the basis of informed guesses based on discussions with industry representatives it is assumed that this trend will develop along the lines shown in table 5.1 This development has been included in our projections.

Further, there is the introduction of the light spare wheel, which requires about 30 percent of the rubber weight compared to a normal tire. This light spare wheel is introduced for reasons of a reduction in weight of the car and thus in energy consumption. It now has fully conquered the USA car industry; however, in other parts of the world it is not popular. Apart from being lighter, it is a bias belted tire, thus containing very little NR.

Projections of new registrations have been derived in chapter 4: five scenario combinations of economic growth rates and saturation levels in car park for passenger cars have been used. They have been the basis for the demand

Table 5.1 *Average number of tires per new passenger car*

	1980	1985	1990	1995	2000
1. USA	5	5	4.9	4.8	4.8
2. Canada	5	5	4.9	4.9	4.8
3. Japan	5	5	4.9	4.8	4.7
4-5. Australia and New Zealand	5	5	5	5	4.9
6. Germany F.R.	5	5	4.9	4.8	4.7
7. France	5	5	4.9	4.8	4.7
8. United Kingdom	5	5	4.9	4.8	4.7
9-14. North-West Europe I	5	5	4.9	4.8	4.7
15-18. North-West Europe II	5	5	4.9	4.8	4.7
19. Italy	5	5	5	4.9	4.8
20-25. Southern Europe	5	5	5	5	4.9
26-32. Eastern Europe	5	5	5	5	5
33-58. Rest of the world	5	5	5	5	5

for original equipment tires, and a disaggregation has been made into conventional tires and radial tires because, as mentioned before, radial tires are heavier and use more rubber than conventional tires and because the share of NR in the elastomer content of radials is higher. Projections of the share of radials, based on historic data, as well as on industry sources and extrapolation, are presented in table 5.2. Multiplying projections of tires for original equipment with the shares of conventional tires and radials gives the component projections for conventional tires and radial tires. The component projections for the standard scenario are summarized in table 5.3.

Commercial vehicles

For commercial vehicles it is extremely difficult to obtain adequate statistical information on the number of tires per vehicle. The main determinant is the average vehicle size. It has been found that for some European countries the share of bigger commercial vehicles in use has been increasing except for Italy. The dominant role of heavy commercial vehicles is intensified by the fact that the life of light commercial vehicles is shorter than the life of heavy trucks. As to factory sales in the USA, shares of different size of

Table 5.2 *Projections of percentage share of radial tires*

				1980	1985	1990	1995	2000
1.	USA	p.c.	O.E.	80	90	95	100	100
			R.P.	55	80	95	100	100
		c.v.	Total	60	80	95	100	100
2.	Canada	p.c.	O.E.	80	90	95	100	100
			R.P.	60	80	95	100	100
		c.v.	Total	60	80	95	100	100
3.	Japan	p.c.	O.E.	65	85	95	100	100
			R.P.	80	95	100	100	100
		c.v.	Total	35	50	80	90	100
4-5.	Australia and	p.c.	Total	60	80	95	100	100
	New Zealand	c.v.	Total	50	70	90	95	100
6.	Germany F.R.	p.c.	Total	95	100	100	100	100
		c.v.	Total	95	100	100	100	100
7.	France	p.c.	Total	100	100	100	100	100
		c.v.	Total	100	100	100	100	100
8.	United Kingdom	p.c.	O.E.	100	100	100	100	100
			R.P.	90	95	100	100	100
		c.v.	Total	85	95	100	100	100
9-14.	North-West	p.c.	Total	95	100	100	100	100
	Europe I	c.v.	Total	95	100	100	100	100
15-18.	North-West	p.c.	Total	90	95	100	100	100
	Europe II	c.v.	Total	90	95	100	100	100
19.	Italy	p.c.	Total	100	100	100	100	100
		c.v.	Total	95	100	100	100	100
20-25.	Southern Europe	p.c.	Total	85	95	100	100	100
		c.v.	Total	70	85	95	100	100
26-32.	Eastern Europe	p.c.	Total	40	60	80	90	95
		c.v.	Total	30	50	70	85	95
33-36.	Latin America	p.c.	Total	40	60	80	90	95
		c.v.	Total	30	50	70	85	95
39-43.	South Asia	p.c.	Total	20	40	60	70	80
		c.v.	Total	20	40	60	70	80
44-52.	East + South-	p.c.	Total	50	70	90	95	100
	East Asia	c.v.	Total	40	60	80	90	95
53-54.	Middle East +	p.c.	Total	50	70	90	95	100
	North Africa	c.v.	Total	40	60	80	90	95
55-58.	Other Middle	p.c.	Total	20	40	60	70	80
	East + Africa	c.v.	Total	20	40	60	70	80

Notes: O.E. = original equipment   p.c. = passenger car
R.P. = replacement   c.v. = commercial vehicle

Table 5.3 *Projections of demand for original equipment tires by type (in thousands) for passenger cars, standard scenario*

		1985	1990	1995	2000
I. North-America	C	5,981	3,610	0	0
	R	53,825	68,755	68,338	73,012
	T	59,806	72,374	68,338	73,012
II. Asia, developed	C	3,072	1,216	0	0
	R	17,408	23,112	23,434	24,543
	T	20,481	24,328	23,434	24,543
III. Oceania, developed	C	823	261	0	0
	R	3,293	4,950	5,269	5,546
	T	4,116	5,211	5,269	5,546
IV. North-West Europe	C	178	0	0	0
	R	46,689	49,137	51,232	52,579
	T	46,868	49,137	51,232	52,579
V. South-West Europe	C	321	0	0	0
	R	15,871	19,831	20,131	22,566
	T	16,193	19,831	20,131	22,566
VI. Eastern Europe	C	3,429	2,466	1,515	952
	R	5,144	9,864	13,637	18,097
	T	8,573	12,330	15,153	19,050
VII. Latin America + Caribbean	C	4,677	4,048	3,120	2,380
	R	7,015	16,192	28,080	45,215
	T	11,692	20,241	31,200	47,595
IX. South Asia	C	774	723	753	664
	R	516	1,085	1,757	2,654
	T	1,290	1,808	2,510	3,318
X. South-East + East Asia	C	885	528	452	0
	R	2,065	4,753	8,588	15,208
	T	2,950	5,281	9,040	15,208
XI. Middle East + North Africa	C	682	326	209	0
	R	1,591	2,932	3,967	5,495
	T	2,273	3,258	4,176	5,495
XII. Other Africa	C	2,209	1,951	1,924	1,633
	R	1,472	2,926	4,489	6,534
	T	3,681	4,877	6,413	8,167

Notes: C = conventional tires
R = radial tires
T = total tires

vehicles did not change much over time. Ideally, commercial vehicles should be divided into groups according to size, especially since very small commercial vehicles normally use passenger car tires. Attempts to do this were not successful, the main bottleneck being non-availability of data. Only the aggregate result is therefore presented.

In consultation with experts and on the basis of several publications, reasonable information has been obtained for some years and for some countries on the number of tires per commercial vehicle. It has been assumed (for want of different evidence) that commercial vehicle size, and therefore the number of tires per commercial vehicle, will not change on average over the foreseeable future. Thus, projections to the year 2000 on the number of tires per commercial vehicle have been derived (see table 5.4). By simply multiplying these data by the number of commercial vehicles newly registered as derived in chapter 4 for three economic scenarios, it is possible to make projections of the number of tires for original equipment, divided into conventional and radial tires on the basis of table 5.2. For each region these projections are presented for the standard economic growth scenario in table 5.5.

Table 5.4 *Estimated number of tires per commercial vehicle*

Countries	*Year 1975 - 2000*
1. USA	8.0
2. Canada	8.0
3. Japan	7.0
4-5. Australia and New Zealand	8.0
6. Germany F.R.	9.0
7. France	8.0
8. United Kingdom	8.0
9-14. North-West Europe I	8.5
15-18. North-West Europe II	8.0
19. Italy	8.0
20-25. Southern Europe	7.5
26-32. Eastern Europe	9.0
33-58. Rest of the world	7.0

Table 5.5 *Projections of demand for original equipment tires by type (in thousands) for commercial vehicles, standard scenario*

		1985	*1990*	*1995*	*2000*
I. North-America	C	6,276	2,238	0	0
	R	25,103	42,517	50,462	56,226
	T	31,379	44,755	50,462	56,226
II. Asia	C	4,859	1,912	0	0
	R	9,023	17,207	24,141	30,552
	T	13,882	19,199	24,141	30,552
III. Oceania, developed	C	368	149	78	0
	R	858	1,344	1,480	1,688
	T	1,226	1,494	1,558	1,688
IV. North-West Europe	C	26	0	0	0
	R	7,612	8,461	8,650	8,713
	T	7,638	8,461	8,650	8,713
V. South-West Europe	C	333	162	0	0
	R	2,680	4,070	4,398	5,127
	T	3,012	4,232	4,398	5,127
VI. Eastern Europe	C	3,636	2,756	1,378	484
	R	3,636	6,432	7,810	9,194
	T	7,272	9,188	9,189	9,678
VII. Latin America + Caribbean	C	2,074	1,746	1,052	368
	R	2,074	4,073	5,960	6,996
	T	4,148	5,818	7,011	7,365
IX. South Asia	C	326	277	220	152
	R	217	416	514	608
	T	543	694	734	760
X. South-East + East Asia	C	613	518	380	240
	R	920	2,072	3,417	4,553
	T	1,534	2,590	3,797	4,793
XI. Middle East + North Africa	C	272	252	147	71
	R	407	1,010	1,324	1,348
	T	679	1,262	1,471	1,419
XII. Other Africa	C	1,877	1,932	1,950	1,775
	R	1,251	2,898	4,550	7,101
	T	3,128	4,830	6,499	8,876

Notes: C = conventional tires
R = radial tires
T = total tires

5.4 TIRES FOR REPLACEMENT

Background information

Demand for replacement tires is determined by tire life which can be derived from tire distance in kilometres divided by driving distance per vehicle in kilometres per year. A complicating factor, however, is the variation in driving distance as well as in tire distance within a country or a region. This is why in the analysis probability distributions have been applied. Further, data on tire distance are not readily available. Therefore, after giving some background information about two of the most important determinants of replacement tire demand in this sub-section, the analysis for the relationship between vehicles, average tire distance, average driving distance and demand for replacement tires will be presented below.

As data on tire production are available over a number of years, the tire replacement model will first be used to estimate average tire distance. Afterwards projections of average tire distance will be made and on the basis of projections of vehicles in use, average tire distance and average driving distance, projections of demand for replacement tires will be derived. Below the analysis is presented for passenger car tires. The analysis for commercial vehicle tires is identical.

Average driving distance

For many countries or regions, only scattered information on driving distance could be obtained. For some countries, however, the data base was more adequate. When analyzing average driving distance for passenger cars for some countries, it becomes clear that while there is in all countries some variation over time, there is far greater variation among countries. This may be due partly to the method of data collection.

Some general conclusions for a few developed countries can be drawn from regression analyses trying to estimate the effects of income per capita, car density and gasoline prices on average driving distance. It was found, first, that income has a very small positive influence on average driving distance for most of the countries investigated. Second, the number of cars in use per 1,000 persons has a negative influence; this can be explained by the growing incidence of second and third cars in a family, by worsening traffic congestion and by the increasing number of cars used solely for holiday purposes. Third, gasoline prices, of course, show a negative coefficient; it can be assumed, however, that the coefficient estimated for the period 1965 to 1977 was too high because driving distance during 1974 was mainly influenced by temporarily extreme gasoline shortages, as well as the extreme reaction thereto, whereas gasoline price showed at that time very little increase, if any.

Using the above factors as a broad basis, projections have been made. These show that for the United States and Canada the slightly declining trend would continue. However, recent forecasts by others for the USA (Beretta (1982)) show a 2 percent increase per year to be caused by a more stable outlook for gasoline. Japan has already experienced a steep decrease in driving distance due to population density and good public transport; this decrease is levelling off and we assume that the minimum will be reached at 8,000 km per year. Car density will become an extremely important factor for Western Europe and to a lesser extent for Oceania; country size and population density are not limiting factors. In the United Kingdom, road conditions are improving causing a slight increase in average driving distance. Projections for Eastern Europe are assumed constant over time for want of better evidence. Although traffic congestion is becoming more and more important in developing countries' major cities, it is assumed not to become a more important factor than income increase for the next 10 years for Latin America and for the next 15 years for the other developing countries. All this has led to assumed average driving distance per region as given in table 5.6.

For commercial vehicles we expect increasing influence from other modes of transport such as container transport by train, particularly for developed countries. Average driving distance per vehicle is therefore projected to decrease slightly by 100 km per year in developed countries (table 5.7).

Tire distance

One of the major problems in this analysis is the determination of the average tire distance, the average number of kilometres achieved with one set of tires of type j ($j = 1$ for conventional tires, be they cross-ply or bias belted, and $j = 2$ for radial tires) as well as changes over time in tire distance for each type.

Table 5.6 *Estimated and projected driving distance per passenger car per year (in 1,000 km)*

	1980[1]	1985	1990	1995	2000
1. USA	15.4	15.9	15.9	15.4	14.4
2. Canada	15.4	15.9	15.9	15.4	14.4
3. Japan	8.5	8.1	8.0	8.0	8.0
4-5. Oceania	16.0	15.0	14.5	14.0	13.5
6. Germany F.R.	12.8	11.8	11.3	10.8	10.3
7. France	12.0	11.5	11.0	10.5	10.0
8. United Kingdom	15.0	15.5	15.5	15.0	14.0
9-14. North-West Europe I	12.0	11.5	11.0	10.5	10.0
15-18. North-West Europe II	12.0	11.5	11.0	10.5	10.0
19. Italy	10.5	10.5	10.0	9.5	9.0
20-25. Southern Europe	11.5	11.5	11.0	10.5	10.0
26-32. Eastern Europe	16.0	16.0	16.0	16.0	16.0
33-36. Latin America	18.0	17.0	16.0	16.0	16.0
40-43. South Asia	20.0	20.0	20.0	19.0	18.0
44-52. East + South-East Asia	19.0	18.0	17.0	16.0	15.0
53-54. Middle East + North Africa (oil)	10.0	9.0	8.0	8.0	8.0
55-58. Other Middle East + Africa	20.0	20.0	20.0	19.0	18.0

1) Source: United Nations, Transport Statistics for Europe
International Road Federation, World Road Statistics
and own estimates based on scattered information.

Table 5.7 *Estimated and projected average driving distance per commercial vehicle in use per year (in 1,000 km)*

	1980[1]	1985	1990	1995	2000
USA	18.0	17.5	17.0	16.5	16.0
Canada	18.0	17.5	17.0	16.5	16.0
Japan	15.0	14.5	14.0	13.5	13.0
Oceania	18.5	18.0	17.5	17.0	16.5
Western Europe	18.0	17.5	17.0	16.5	16.0
Eastern Europe	19.0	18.5	18.0	17.5	17.0
Latin America	20.0	20.0	20.0	20.0	20.0
Rest of the world	20.0	20.0	20.0	20.0	20.0

1) Source: see table 5.6.

Some factors affecting tire distance change over time and differ among countries. Three types of factors are relevant. The first is the security aspect, be it legal or personal. In the United Kingdom, for instance, tire distance has decreased considerably as a result of increased safety consciousness; in particular, a 1968 law on the minimum tread depth of tires created a boom in the demand for replacement tires. Safety consciousness and security regulations also provide a major explanation of the difference in tire distance among countries. Tire distance in many developing countries, by comparison, can on these terms be expected to be relatively high.

The second influence on tire distance consists of factors like the positive relationship of tire weight and size to tire distance. This is the main cause, for instance, of the difference in tire distance between the United States and Japan. Finally, we have already mentioned driving style and road conditions: how powerful are the engine and the brakes; is the road a congested city street, a super highway or a dirt road; is driving speed over 100 km per hour allowed; and so forth.

An important problem in estimating tire distance is the availability of accurate and properly disaggregated tire data. We shall just mention a few aspects of the tire data which are a cause of inaccuracy:

- An important category of vehicles is the car derived van, which is of the passenger car station-wagon type constructed for transportation of goods. They use normal or slightly reinforced passenger car tires, which can not be found separately in data sources.
- Some other light vans (pick-up trucks etc.) may use reinforced passenger car tires as well.
- Tires for replacement can be either new tires or retreaded tires. Vast improvements in technology in recent years have succeeded in raising tire distance for a retreaded tire to about the same level as for a new tire. For this reason no reduction was made in tire distance for retreaded tires compared to new tires. The share of retreading in total tire replacement for passenger cars has decreased in the 1970's mainly due to the already longer life of radial tires, technical difficulties in adequately retreading a radial tire and insufficient supply of tires to be retreaded, mainly due to carcass damage. Since the tire industry now seems to have overcome these problems and because of related material savings and lower prices, an increased retread share may be expected in the future although a maximum of 25 percent seems realistic for passenger cars (see table 5.8).

Data about retreads, understandably, are not very good.

- For commercial vehicles retreading has remained very important due to the relatively high share of tire costs in total costs of running a commercial vehicle. After consultation of expert opinion from industry sources, the share of retreaded tires in total replacement has been assumed to develop in the future as presented in table 5.9.
- An other important factor affecting tire distance for heavy commercial vehicles is the possibility of regrooving: as the tread cannot be too thick for stability reasons and the belt consists of a rather thick layer of rubber , some 2-3 millimetres can be cut out after the depth of the tread has reduced. The tire may afterwards still be retreaded. This will again add to tire distance.
- One factor which has not been taken into account is the possible introduction of the wide-base truck tire, thus replacing two tires each. This will only be important for heavy duty truck tires and may not dramatically affect total rubber demand.
- Import of tires by domestic tire manufacturers may not have been properly distinguished from domestic production. Illegal imports may also affect accuracy.

It is essential, in conclusion, to be careful with estimation results, and to incorporate results from other studies or expert opinions.

Table 5.8 *Estimated and projected percentage share of retreaded tires in replacement of passenger car tires, conventional and radial*

Country/region		*1980*	*1985*	*1990*	*1995*	*2000*
North-America	C	20	25	25	25	25
	R	10	15	20	25	25
Japan	C	15	20	25	25	25
	R	10	15	20	25	25
Oceania	C	10	15	20	25	25
	R	5	10	15	15	20
Western Europe	C	20	25	25	25	25
	R	10	15	20	25	25
Eastern Europe	C	10	15	15	20	25
	R	5	5	10	15	20
Latin America	C	5	10	10	15	20
	R	2	5	5	10	15
Rest of the world	C	5	5	10	10	15
	R	2	2	5	5	10

Table 5.9 *Estimated and projected percentage share of retreaded tires in replacement of commercial vehicle tires, conventional and radial*

Country/region		*1980*	*1985*	*1990*	*1995*	*2000*
North-America	C	40	40	40	45	45
	R	30	35	40	40	45
Japan	C	45	45	45	45	45
	R	30	35	40	45	45
Oceania	C	40	45	45	45	45
	R	25	30	35	40	45
Western Europe	C	40	45	45	45	45
	R	30	35	40	45	45
Eastern Europe	C	40	45	45	45	45
	R	25	30	35	40	45
Latin America	C	20	25	25	30	30
	R	5	10	15	20	20
Rest of the world	C	10	15	20	20	25
	R	0	5	10	15	15

Notes: C = conventional tires
R = radial tires

Estimation results and projections

While taking world totals of tire production in view of the data problems, one should keep the various parameters and explanatory variables as country specific as possible. They are

- average tire distance for each type
- average driving distance
- vehicles in use, new registrations and discards
- shares of radial tires
- shares of retreaded tires.

Except for the first item, average tire distance per type per year per region, all data and estimates as well as projections have been given in previous chapters or sections.

Starting point for the analysis is a series of data on world tire production, both for passenger cars and commercial vehicles (table 5.10). The sample period has been restricted to 1975-1980 for a number of reasons:

- the years 1973-1974 were not representative because of the oil crisis
- before 1970 data on world tire production were not as accurate as those presented by the International Rubber Study Group and given in table 5.10.

- it was decided that information concerning the ratio between radial tire distance and conventional tire distance as well as developments over time in both variables could best be based on industry sources taking into account such factors as (expected) composition of the car park, road conditions and developments in the tire industry
- as the only parameter to be estimated was average tire distance, it was not necessary to have a long time series.

After deduction of tires for original equipment, as shown in section 5.3., data on tires for replacement are available.

Table 5.10 *World tire production (in millions)*

	passenger car tires	*commercial vehicle tires*
1975	427.1	122.7
1976	458.1	136.8
1977	497.8	153.9
1978	490.5	165.1
1979	490.0	172.0
1980	460.0	168.0

Source: International Rubber Study Group (1982).

A priori information on differences in average tire distance between types and between countries is partly available from statistics and industry sources. On this basis, for each region average tire distance and its annual increase for each type is assumed to have a fixed ratio to a basic world wide estimate of average tire distance per type, thus allowing for country specific differences. The estimation starts with assumed figures for average tire distance for the two types of tires and their increase over time. A proportionality factor is then estimated in order to achieve a good fit with production figures for replacement tires. Retreaded tires have been included. The resulting estimated and projected figures for tire distance are given in table 5.11.

The last step is to use these projections to determine tire demand projections. Using the probability distribution for tire distance, including projected average tire distance and combining this through the model with projections of driving distance per year (tables 5.6 and 5.7), projections of the demand for tires for replacement for passenger cars and commercial vehicles have been made both for new and retreaded tires by using tables 5.8 and 5.9. Some of the results appear in the following tables.

Table 5.11 *Estimated and projected tire distance of conventional and radial tires for passenger cars and commercial vehicles (in 1,000 km)*

		Passenger car tires		*Commercial vehicle tires*	
		1980	*2000*	*1980*	*2000*
1. USA	C	30.2	33.6	45.2	53.8
	R	47.0	50.4	72.2	86.0
2. Canada	C	30.2	33.6	45.2	53.8
	R	47.0	50.4	72.2	86.0
3. Japan	C	22.3	27.3	31.8	38.7
	R	39.9	48.3	54.2	64.5
4-5. Australia +	C	27.7	31.1	40.9	49.5
New Zealand	R	45.8	50.8	72.2	86.0
6. Germany F.R.	C	26.5	31.5	45.2	53.8
	R	44.1	52.5	81.3	96.8
7. France	C	23.9	29.0	40.9	49.5
	R	39.9	48.3	77.0	92.5
8. United Kingdom	C	24.8	29.8	40.9	49.5
	R	42.4	50.8	72.2	86.0
9-14. North-West Europe I	C	23.9	29.0	40.9	49.5
	R	39.9	48.3	77.0	92.5
15-18. North-West Europe II	C	23.9	29.0	36.1	43.0
	R	39.9	48.3	67.9	81.7
19. Italy	C	23.1	28.1	36.1	43.0
	R	38.6	45.4	67.9	81.7
20-25. Southern Europe	C	22.3	27.3	31.8	38.7
	R	37.0	43.7	54.2	64.5
26-32. Eastern Europe	C	23.9	29.0	36.1	43.0
	R	35.3	42.0	67.9	81.7
33-36. Latin America	C	22.3	27.3	36.1	43.0
	R	30.7	35.7	58.9	71.0
39-58. Rest of the world	C	23.9	29.0	36.1	43.0
	R	33.2	38.2	58.9	71.0

Notes: C = Conventional tires
R = Radial tires

From table 5.12 one may conclude that for the standard scenario, growth in demand for replacement tires for passenger cars cannot be envisaged for the USA, and the North-West European countries. In many cases there will be a decrease because the ratio of tire distance and driving distance increases. Besides, for Western Europe, growth in car park is very limited. Some of the other developed countries as well as the developing countries show a wide scope for increase in tire demand for replacement of worn-out tires for passenger cars.

For commercial vehicles similar conclusions may be drawn (cf. table 5.13). Countries or regions without growth in demand for replacement tires, are in this case Canada, Oceania and the North-West European countries. For most developing countries reasonable growth rates in demand for replacement tires can be anticipated.

Tables 5.14 and 5.15 show the projections for the need for new tires; this is original equipment tires plus replacement tires minus retreaded tires, thus combining the results of section 5.3 with this section. Growth in demand for new tires is expected for all regions except North-West Europe, both for passenger cars and commercial vehicles. Until 1985 growth will be very limited. Passenger car tire demand will be around the level of the late seventies or only slightly higher. This is particularly true for passenger cars. After 1985 various economic growth scenarios show a dramatic influence. Effects of different scenarios will be analyzed again in chapter 6 where demand for tires is translated into demand for rubber.

Table 5.12 *Projections of demand for replacement tires by type (in thousands) for passenger cars, standard scenario*

		1985	1990	1995	2000
1. USA	C	30,197	7,489	0	0
	R	120,790	142,299	154,433	151,473
	T	150,987	149,788	154,433	151,473
2. Canada	C	2,807	782	0	0
	R	11,226	14,863	17,256	17,147
	T	14,033	15,645	17,256	17,147
3. Japan	C	824	0	0	0
	R	15,660	19,322	21,259	19,202
	T	16,484	19,322	21,259	19,202
4-5. Australia and New Zealand	C	1,808	489	0	0
	R	7,232	9,292	10,855	11,234
	T	9,040	9,781	10,855	11,234
6. Germany F.R.	C	0	0	0	0
	R	20,525	21,242	19,349	17,470
	T	20,525	21,242	19,349	17,470
7. France	C	0	0	0	0
	R	15,180	14,994	15,345	15,244
	T	15,180	14,994	15,345	15,244
8. United Kingdom	C	821	0	0	0
	R	15,597	15,591	15,020	14,049
	T	16,418	15,591	15,020	14,049
9-14. North-West Europe I	C	0	0	0	0
	R	10,891	11,943	11,734	10,962
	T	10,891	11,943	11,734	10,962
15-18. North-West Europe II	C	290	0	0	0
	R	5,507	6,329	6,368	5,880
	T	5,797	6,329	6,368	5,880
19. Italy	C	0	0	0	0
	R	16,841	18,489	19,920	18,983
	T	16,841	18,489	19,920	18,983
20-25. Southern Europe	C	671	0	0	0
	R	12,742	14,475	16,077	17,683
	T	13,413	14,475	16,077	17,683
26-32. Eastern Europe	C	9,364	5,506	3,535	2,136
	R	14,046	22,025	31,814	40,588
	T	23,410	27,531	35,349	42,724

Table 5.12 (continued)

		1985	1990	1995	2000
33-36. Latin America	C	15,768	9,914	7,153	5,122
	R	23,653	39,654	64,381	97,309
	T	39,421	49,568	71,535	102,430
39-43. South Asia	C	2,509	2,268	2,212	1,841
	R	1,673	3,402	5,162	7,365
	T	4,181	5,669	7,375	9,206
44-52. East + South-East Asia	C	2,329	1,119	828	0
	R	5,434	10,074	15,741	25,216
	T	7,763	11,194	16,570	25,216
53-54. Middle East + North Africa	C	1,098	384	244	0
	R	2,561	3,459	4,643	6,088
	T	3,659	3,844	4,887	6,088
55-58. Other Africa	C	9,400	7,647	6,788	5,219
	R	6,267	11,471	15,839	20,874
	T	15,666	19,118	22,627	26,093

Notes: C = conventional tires
R = radial tires
T = total tires

Table 5.13 *Projections of demand for replacement tires by type (in thousands) for commercial vehicles, standard scenario*

		1985	1990	1995	2000
1. USA	C	10,825	2,856	0	0
	R	43,300	54,271	63,414	68,739
	T	54,125	57,127	63,414	68,739
2. Canada	C	876	211	0	0
	R	3,504	4,018	4,360	4,350
	T	4,380	4,229	4,360	4,350
3. Japan	C	8,191	2,635	0	0
	R	15,213	23,712	29,223	35,168
	T	23,404	26,347	29,223	35,168
4-5. Australia and New Zealand	C	890	267	131	0
	R	2,077	2,405	2,518	2,654
	T	2,967	2,672	2,650	2,654
6. Germany F.R.	C	0	0	0	0
	R	2,124	1,986	1,881	1,764
	T	2,124	1,986	1,881	1,764
7. France	C	0	0	0	0
	R	2,684	2,589	2,632	2,509
	T	2,684	2,589	2,632	2,509

Table 5.13 (continued)

		1985	1990	1995	2000
8. United Kingdom	C	0	0	0	0
	R	2,246	2,182	2,144	2,022
	T	2,246	2,182	2,144	2,022
9-14. North-West Europe I	C	0	0	0	0
	R	1,626	1,664	1,760	1,773
	T	1,626	1,664	1,760	1,773
15-18. North-West Europe II	C	63	0	0	0
	R	1,204	1,194	1,201	1,189
	T	1,268	1,194	1,201	1,189
19. Italy	C	0	0	0	0
	R	1,089	1,019	1,127	1,117
	T	1,089	1,019	1,127	1,117
20-25. Southern Europe	C	824	273	0	0
	R	4,669	5,183	5,929	6,462
	T	5,493	5,456	5,929	6,462
26-32. Eastern Europe	C	8,906	4,817	2,333	737
	R	8,906	11,241	13,222	14,000
	T	17,812	16,058	15,555	14,737
33-36. Latin America	C	8,863	5,333	2,772	968
	R	8,863	12,444	15,710	18,386
	T	17,726	17,778	18,482	19,354
39-43. South Asia	C	1,243	875	711	512
	R	829	1,313	1,659	2,047
	T	2,072	2,188	2,370	2,559
44-52. East + South-East Asia	C	2,107	1,207	708	458
	R	3,160	4,827	6,372	8,695
	T	5,267	6,033	7,079	9,153
53-54. Middle East + North Africa	C	1,889	885	425	229
	R	2,833	3,538	3,826	4,345
	T	4,722	4,423	4,251	4,574
55-58. Other Africa	C	4,692	4,111	4,129	3,559
	R	3,128	6,167	9,634	14,235
	T	7,820	10,278	13,763	17,794

Notes: C = conventional tires
R = radial tires
T = total tires

Table 5.14 *Projections of demand for new tires (in thousands) for passenger cars, 5 scenarios*

		scenario	1985	1990	1995	2000
World total	C	a	83,976	40,105	21,117	13,285
		b	87,910	44,819	25,770	17,329
		c	88,134	45,336	25,770	17,329
		d	91,796	49,275	30,073	21,419
		e	92,170	49,832	30,073	21,419
	R	a	399,744	470,134	505,728	547,869
		b	415,343	503,236	562,112	641,721
		c	419,334	518,226	582,509	665,279
		d	433,444	543,649	629,512	753,715
		e	438,808	560,169	652,000	778,918
	T	a	483,720	510,239	526,845	561,154
		b	503,252	548,055	587,883	659,050
		c	507,468	563,563	608,279	682,608
		d	525,240	592,924	659,585	775,134
		e	530,977	610,001	682,073	800,337

Table 5.15 *Projections of demand for new tires (in thousands) for commercial vehicles, 3 scenarios*

		scenario	1985	1990	1995	2000
World total	C	G1	50,238	25,268	11,710	6,349
		G2	53,859	28,055	13,340	7,754
		G3	57,927	31,441	15,452	9,621
	R	G1	123,805	163,437	179,622	193,623
		G2	133,891	187,057	219,439	252,750
		G3	145,120	215,290	270,153	332,725
	T	G1	174,043	188,704	191,331	199,972
		G2	187,750	215,112	232,779	260,504
		G3	203,047	246,731	285,605	342,346

6. ANALYSIS AND PROJECTIONS OF WORLD RUBBER DEMAND

6.1 INTRODUCTION

World rubber consumption has increased dramatically in the past two decades, even though the world economic recession in the late seventies severely depressed the rubber market. A rough picture of the development of rubber consumption is given in table 6.1. While for the world as a whole, rubber consumption has more than tripled between 1960-1980, some countries have shown a more moderate though still substantial increase: USA, Germany F.R., France and especially the United Kingdom. Extremely high growth rates over the past two decades have been achieved by e.g. Brazil, Japan, some developing countries and Eastern Europe.

Table 6.1 *Total rubber consumption 1965-1980 (in tonnes)*

	1965	*1970*	*1975*	*1980*
USA	2,087,794	2,516,918	2,629,685	2,565,000
Canada	141,165	186,082	251,557	280,000
Brazil	64,413	122,093	235,050	324,884
Germany F.R.	366,384	558,812	556,991	600,997
France	276,963	419,150	433,873	529,619
United Kingdom	369,400	461,800	436,800	379,000
Italy	200,000	310,000	338,000	420,000
Japan	377,000	779,000	870,000	1,312,000
Sub-total	3,883,119	5,353,855	5,751,956	6,411,500
Rest of the world excl. E. Europe and China	851,631	1,496,145	1,888,544	2,633,500
Total excl. Eastern Europe and China	4,734,750	6,850,000	7,640,500	9,045,000
Eastern Europe and China	620,250	1,785,000	2,755,000	3,375,000
Grand Total World	5,355,000	8,635,000	10,395,000	12,420,000

Source: Rubber Statistical Bulletin

Data on rubber consumption split up between the tire sector and the non-tire sector are available for a limited number of countries only (see tables 6.2 and 6.3). These eight countries accounted for a large although declining share of world rubber consumption: 74.4 percent in 1960, 62.0 percent in 1970 and 51.6 percent in 1980. From tables 6.2 and 6.1 the percentage share of the tire sector in total rubber consumption can be derived. For the eight countries together this share is remarkably stable over time.

The next section of this chapter discusses non-tire rubber demand, while section 6.3 focusses again on the tire sector. Section 6.4 finally adds the two sectors in order to arrive at total world demand for rubber.

Table 6.2 *Rubber consumption in the tire sector (in tonnes)*

	1955	*1960*	*1965*	*1970*	*1975*	*1980*
USA	975,213	1,010,786	1,327,309	1,602,912	1,643,808	1,520,960
Canada	56,717	64,213	100,349	144,953	171,916	198,000
Brazil	n.a.	47,497	45,637	79,603	147,215	203,405
Germany F.R.	n.a.	139,550	207,400	284,000	262,420	275,070
France	92,179	126,052	160,369	262,427	283,677	354,497
United Kingdom	147,726	158,200	193,200	233,400	213,900	182,900
Italy	n.a.	71,000	111,000	159,000	161,900	176,000
Japan	n.a.	99,070	182,750	399,000	540,100	833,500
Total	n.a.	1,716,368	2,328,014	3,165,295	3,424,936	3,744,332

Source: Rubber Statistical Bulletin

Table 6.3 *Rubber consumption in the non-tire sector (in tonnes)*

	1955	*1960*	*1965*	*1970*	*1975*	*1980*
USA	578,961	572,513	760,485	914,006	987,877	1,044,040
Canada	29,163	28,282	40,816	41,129	92,108	92,500
Brazil	n.a.	13,664	18,776	42,490	87,835	121,479
Germany F.R.	n.a.	114,550	158,984	274,812	294,571	325,927
France	64,076	95,573	116,594	156,723	150,196	155,122
United Kingdom	126,187	142,300	176,200	228,400	222,900	196,100
Italy	n.a.	62,000	89,000	151,000	176,100	244,000
Japan	n.a.	130,930	194,250	380,000	329,900	478,500
Total	n.a.	1,159,812	1,555,105	2,188,560	2,341,487	2,657,668

Source: Rubber Statistical Bulletin

6.2 NON-TIRE RUBBER DEMAND

General information

As was stated in chapter 1, specific non-tire end-uses for rubber number in the thousands. To mention a few: rubber thread, rubberised cloth, footwear, window strips, engine mouldings, conveyor belts, hoses, rubber sheets, roofing sheets, rubber gloves, carpet backing, elastic rubber bands, fishing ropes and soft-balls. It goes without saying that availability of data but also of manpower and time are barriers in undertaking a detailed analysis of all possible end-uses.

Even if these constraints were not relevant, the next barrier would be the availability of information about the rubber content of the various products. It is not easily possible to determine the rubber content of such a thing as the average conveyor belt. First, even conveyor belts can be found in many different types and, second, the mix of materials prevents the researcher from singling out the rubber content.

A way out is to focus on the countries where the rubber products are produced, because it is there where disappearance of rubber might be traced.

Many products, which were end-uses of rubber in the past, are now partially or completely made of plastics. Hence products disappear from the rubber scene and new ones emerge. This strongly complicates the analysis, because, even if one might be able to forecast disappearance of an end-use, it is quite impossible to accurately predict which new end-uses may come to the fore and how much impact they will have.

Data on rubber consumption by non-tire end-uses as a whole are available for seven (groups of) countries: United States and Canada, Japan, Germany F.R., France, United Kingdom, Italy and Brazil. Figures for the USA and Canada, for Japan and for Italy show a trough in 1975 while recovery is seen afterwards, although recovery in Japan is seen at a lower level. The decline in non-tire rubber consumption continued until 1976 in Germany and 1977 in France. The United Kingdom is a special case: after recovery in 1976 there has been an almost steady decline ever since. The country which hardly seems to have been affected by oil crisis or recession is Brazil.

Analysis and projections of non-tire rubber demand

Within the scope of this study, non-tire rubber demand can be analyzed at an aggregate level only. One must therefore find explanatory variables determining developments in total non-tire rubber demand. A plausible variable may be an index of industrial production. On the other hand, using GDP should be advantageous because all projections thus far have been based on GDP--scenarios. From the quality of the fit of the regression analyses, it became clear that the use of an index of (manufactured) industrial production did not provide better results than GDP. As a considerable part of non-tire end-uses has the automotive industry as its destination, it has been tried to also include vehicle production as an explanatory variable. Results were by no means satisfactory. All regression analyses are based on the period 1960-1980 except for the United Kingdom, where the starting year is 1961.

Owing to data limitations, as has been argued above, it was not possible to find out demand for a non-tire end-use in the country where the product is actually used. By relating the demand to GDP in the country where the product is produced, one does not take into account the international trade aspect which may make the model less stable. However, this could not be avoided within the context of this study.

For the rest of the world, excluding the eight countries, data do not allow an analysis as has been undertaken for the eight countries. On the basis of scattered information from various sources, it is at best possible to arrive at a tentative conclusion only. While non-tire rubber demand for the above mentioned eight countries is about 40 percent of their total rubber demand (cf. tables 6.2, 6.3) for the rest of the world tires will take a smaller share and non-tire demand is about 50 percent of their total rubber demand. Using this figure for computing non-tire rubber consumption, the relationship with GDP for this region has been analyzed.

This relationship, however crudely it is estimated, completes the analysis of world non-tire rubber demand. Note that the Asian Centrally Planned Economies have been excluded thus far from the analysis because of lack of information. Some assumptions will be made for these Economies at a later stage to complete the global picture.

Projections

Projections are derived on the basis of the above mentioned relationships and the three economic scenarios G1, G2 and G3 as described in Appendix A. Table 6.4 presents the results for the world (excl. Asian CPEC) divided into the eight countries and the rest of the world.

Table 6.4 *Projections of world non-tire rubber demand (excl. Asian CPEC), in 1,000 tonnes, see text*

		1985	*1990*	*1995*	*2000*
Aggregated eight countries	G1	2,407	2,922	3,408	3,820
	G2	2,638	3,604	4,641	5,675
	G3	2,881	4,365	6,115	8,041
Rest of the world (excl. Asian CPEC)	G1	3,045	3,558	4,097	4,629
	G2	3,196	4,016	4,907	5,854
	G3	3,376	4,592	5,984	7,565
World total (excl. Asian CPEC)	G1	5,451	6,481	7,506	8,450
	G2	5,834	7,620	9,549	11,529
	G3	6,257	8,957	12,098	15,606

6.3 RUBBER DEMAND IN THE TIRE SECTOR

Rubber demand for passenger car tires

Deriving rubber demand for passenger car tires from estimates of the number of tires demanded - as presented in the previous chapter - is a rather straightforward exercise: multiplying tires by their respective rubber weight. Some questions need to be answered:

- what is the average rubber weight of a passenger car tire
- what is the difference between conventional tires and radial tires
- is a change in rubber weight to be anticipated
- what is the reduction in elastomer use when retreading a tire?

A major problem in this exercise is to derive good estimates of the rubber weight of different types of tires. Scattered information is available in published and unpublished sources showing rubber weight of various types of tires by country and over time. These statistics indicate that there is considerable variation among countries but not much variation over time except for such countries as the USA in recent years. We used these sources to obtain estimates for rubber weight of passenger car tires in the major countries, including the United States, Japan and certain EEC countries.

These estimates vary by country depending on the average size of passenger cars. For countries or regions for which no adequate direct information could be obtained, elastomer weight per tire has been estimated by assessing average car size. From additional information, radial tires have been estimated to contain 10 percent more rubber per tire than conventional tires. Finally, rubber weight per tire had to be consistent with total absorption of rubber. On this basis, the original estimates had to be increased with 10-20 percent. A reason may be waste during the production process. Therefore the concept rubber weight per tire needs to be defined as rubber needs per tire. Elastomer content of retreaded tires has to be dealt with separately since these tires absorb far less (new) rubber. The reduction in elastomer requirement has been estimated at 55 percent, based on various statistical sources and discussions with experts.

The final estimation results concerning elastomer weight are presented in table 6.5. A small decrease is anticipated for the USA, Canada and Australia and New Zealand because of a reduction in car size. The results of the multiplication of numbers of tires and their respective rubber weights are presented in table 6.6 for world totals for 5 scenarios.

Rubber demand for commercial vehicle tires

The determination of rubber demand for commercial vehicle tires follows the same system as for passenger car tires. The same problems are also encountered. Elastomer weight estimates of commercial vehicle tires, however, are even more difficult to obtain. About half of commercial vehicles use large rim diameter passenger car tires. The rest differ considerably, depending on vehicle size and number of axles. Information for some sizes of commercial vehicle tires has been obtained. Using weighted averages and introducing some adjustments we arrived at the figures presented in table 6.7 . Countries and regions for which no information was available were treated in the same way as in the case of passenger car tires. Subsequently rubber demand for commercial vehicle tires can be calculated. Results are shown in table 6.8 for world totals for 3 scenarios.

Table 6.5 *Rubber weights of passenger car tires (in kg)*

		1980	1985	1990	1995	2000
1. USA	C	5.9	5.8	5.7	5.6	5.5
	R	6.5	6.4	6.3	6.1	6.0
2. Canada	C	5.8	5.7	5.6	5.4	5.3
	R	6.4	6.2	6.1	6.0	5.9
3. Japan	C	4.5	4.5	4.5	4.5	4.5
	R	5.0	5.0	5.0	5.0	5.0
4-5. Australia and	C	5.8	5.7	5.6	5.4	5.3
New Zealand	R	6.4	6.3	6.1	6.0	5.9
6. Germany F.R.	C	5.2	5.2	5.2	5.2	5.2
	R	5.7	5.7	5.7	5.7	5.7
7. France	C	5.1	5.1	5.1	5.1	5.1
	R	5.6	5.6	5.6	5.6	5.6
8. United Kingdom	C	5.1	5.1	5.1	5.1	5.1
	R	5.6	5.6	5.6	5.6	5.6
9-14. North-West	C	5.1	5.1	5.1	5.1	5.1
Europe I	R	5.6	5.6	5.6	5.6	5.6
15-18. North-West	C	5.0	5.0	5.0	5.0	5.0
Europe II	R	5.5	5.5	5.5	5.5	5.5
19. Italy	C	4.9	4.9	4.9	4.9	4.9
	R	5.4	5.4	5.4	5.4	5.4
20-25. Southern Europe	C	4.8	4.8	4.8	4.8	4.8
	R	5.2	5.2	5.2	5.2	5.2
26-32. Eastern Europe	C	5.0	5.0	5.0	5.0	5.0
	R	5.5	5.5	5.5	5.5	5.5
33-58. Rest of the	C	4.7	4.7	4.7	4.7	4.7
world	R	5.1	5.1	5.1	5.1	5.1

Notes: C = conventional tires
R = radial tires

Table 6.6 *Projections of rubber demand for passenger car tires (in 1,000 tonnes), 5 scenarios*

	scenario	*1985*	*1990*	*1995*	*2000*
World total (excl. Asian CPEC)	a	2,752	2,908	3,023	3,198
	b	2,852	3,112	3,350	3,717
	c	2,875	3,196	3,470	3,856
	d	2,964	3,354	3,738	4,337
	e	2,994	3,447	3,871	4,486

Table 6.7 *Elastomer weight of commercial vehicle tires (in kg)*

		1980-2000
1. USA	C	22.6
	R	24.9
2. Canada	C	22.6
	R	24.9
3. Japan	C	13.6
	R	14.7
4-5. Australia + New Zealand	C	22.6
	R	24.9
6. Germany F.R.	C	27.1
	R	29.9
7. France	C	24.9
	R	27.1
8. United Kingdom	C	23.7
	R	26.0
9-14. North-West Europe I	C	26.0
	R	28.3
15-18. North-West Europe II	C	23.7
	R	26.0
19. Italy	C	22.6
	R	24.9
20-25. Southern Europe	C	20.3
	R	22.6
26-32. Eastern Europe	C	22.6
	R	24.9
33-36. Latin America	C	13.6
	R	14.7
39-43. South Asia	C	12.4
	R	13.6
44-52. East + South-East Asia	C	13.6
	R	14.7
53-54. Middle East + North Africa	C	14.7
(oil)	R	15.8
55-58. Other Africa	C	12.4
	R	14.7

Notes: C = conventional tires
R = radial tires

Table 6.8 *Projections of rubber demand for commercial vehicle tires (in 1,000 tonnes), 3 scenarios*

	scenario	*1985*	*1990*	*1995*	*2000*
World total (excl. Asian CPEC)	G1	4,084	4,422	4,497	4,639
	G2	4,379	5,020	5,454	6,021
	G3	4,705	5,731	6,664	7,878

Rubber demand for other tires

Thus far, rubber demand has been derived and projected for passenger car tires and commercial vehicle tires. This leaves untreated those groups of tires used for tractors, aeroplanes, motorcycles, scooters and bicycles as well as all tubes. Together these uses may be estimated at about 8 percent of tire rubber consumption for the group of eight countries listed in section 6.2 and about 15 percent of tire rubber consumption for the rest of the world (excluding Asian Centrally Planned Economies) during the second half of the seventies. We relate this end-use to GDP for the two groups for this period.

Using the GDP-scenarios from Appendix A, one arrives at projections as presented in table 6.9.

Table 6.9 *Projections of rubber demand (excl. Asian Centrally Planned Economies) for tires other than those for passenger cars and commercial vehicles (in 1,000 tonnes), for 3 scenarios*

	scenario	*1985*	*1990*	*1995*	*2000*
Group of eight countries	G1	271	306	337	362
	G2	289	354	421	487
	G3	308	407	522	647
Rest of the world (excl. Asian CPEC)	G1	435	519	607	695
	G2	460	594	740	895
	G3	489	688	916	1,175
World (excl. Asian CPEC)	G1	706	825	944	1,057
	G2	748	947	1,160	1,382
	G3	797	1,095	1,438	1,822

On a world scale the share of rubber for other tires compared to total rubber demand for tires increases slightly over time: 9.6 percent in 1980, 10.3 percent in 1990 and 12.3 percent in 2000. The major reason is lagging behind of passenger car tires because of saturation and reduction in driving distance, as well as radial tire technology.

Rubber demand in the tire sector

Thus far, all components of rubber demand for tires have been projected (excluding Asian Centrally Planned Economies). By simply adding up these results one obtains table 6.10. For passenger car tires, scenario a has been used for G1, scenario c for G2 and scenario e for G3.

Table 6.10 *Projections of world rubber demand in the tire sector (in 1,000 tonnes), excluding Asian CPEC)*

	scenario	*1985*	*1990*	*1995*	*2000*
Tires, total	G1	7,543	8,155	8,464	8,894
	G2	8,002	9,163	10,084	11,259
	G3	8,496	10,273	11,973	14,186

6.4 WORLD DEMAND FOR RUBBER

In sections 6.2 and 6.3 world demand for rubber in the non-tire sector and the tire sector has been derived. Aggregating these two sectors by adding the totals of table 6.4 and table 6.10, world demand for rubber (excluding Asian Centrally Planned Economies) is obtained. Results are shown in table 6.11.

Table 6.11 *Projections of world rubber demand (in 1,000 tonnes) for 3 scenarios*

	scenario	*1985*	*1990*	*1995*	*2000*
World (excl. Asian CPEC)	G1	12,994	14,635	15,970	17,344
	G2	13,836	16,783	19,633	22,787
	G3	14,753	19,231	24,071	29,793

No attention has been paid thus far to the case of China (and the other Asian Centrally Planned Economies). It needs no further clarification that it is extremely difficult to obtain information on the structure of rubber consumption and its relationship to such indicators as income and production for these countries. In order to complete the picture, we might roughly assess the effects of growth in GDP in China on rubber consumption, assuming an elasticity of 1.5, which presumably is as good a guesstimate as any other. Further basis for the analysis is estimated rubber consumption in 1980, amounting to 450,000 tonnes. Results are presented in table 6.12. To these projections some approximations for rubber demand for other Asian Centrally Planned Economy Countries will be added (cf. table 6.12).

Table 6.12 *Projections of rubber demand in Asian Centrally Planned Economies (in 1,000 tonnes)*

	scenario	*1985*	*1990*	*1995*	*2000*
Asian CPEC excl. China		25	30	35	40
China	G1	467	522	563	584
	G2	495	609	706	789
	G3	510	659	821	987
Asian CPEC, total	G1	492	552	598	624
	G2	520	639	741	829
	G3	535	689	856	1,027

Combining tables 6.11 and 6.12 gives total world rubber demand for 1985, 1990, 1995 and 2000, as shown in table 6.13. This shows some increase in rubber demand for the low growth scenario G1 with an average annual growth rate of 1.8 percent. For the other scenarios, the average annual growth rates over the remaining decades of the century are 3.3 percent and 4.6 percent, respectively. A graph for world rubber demand on the basis of table 6.13 is given in figure 6.1.

Table 6.13 *Estimated and projected world rubber demand (in 1,000 tonnes) for 3 scenarios*

	scenario	*1955*	*1960*	*1965*	*1970*	*1975*
World total		2,945	3,865	5,355	8,635	10,395
		1980	*1985*	*1990*	*1995*	*2000*
World total	G1	12,445	13,486	15,187	16,568	17,968
	G2		14,356	17,422	20,374	23,616
	G3		15,288	19,920	24,927	30,820

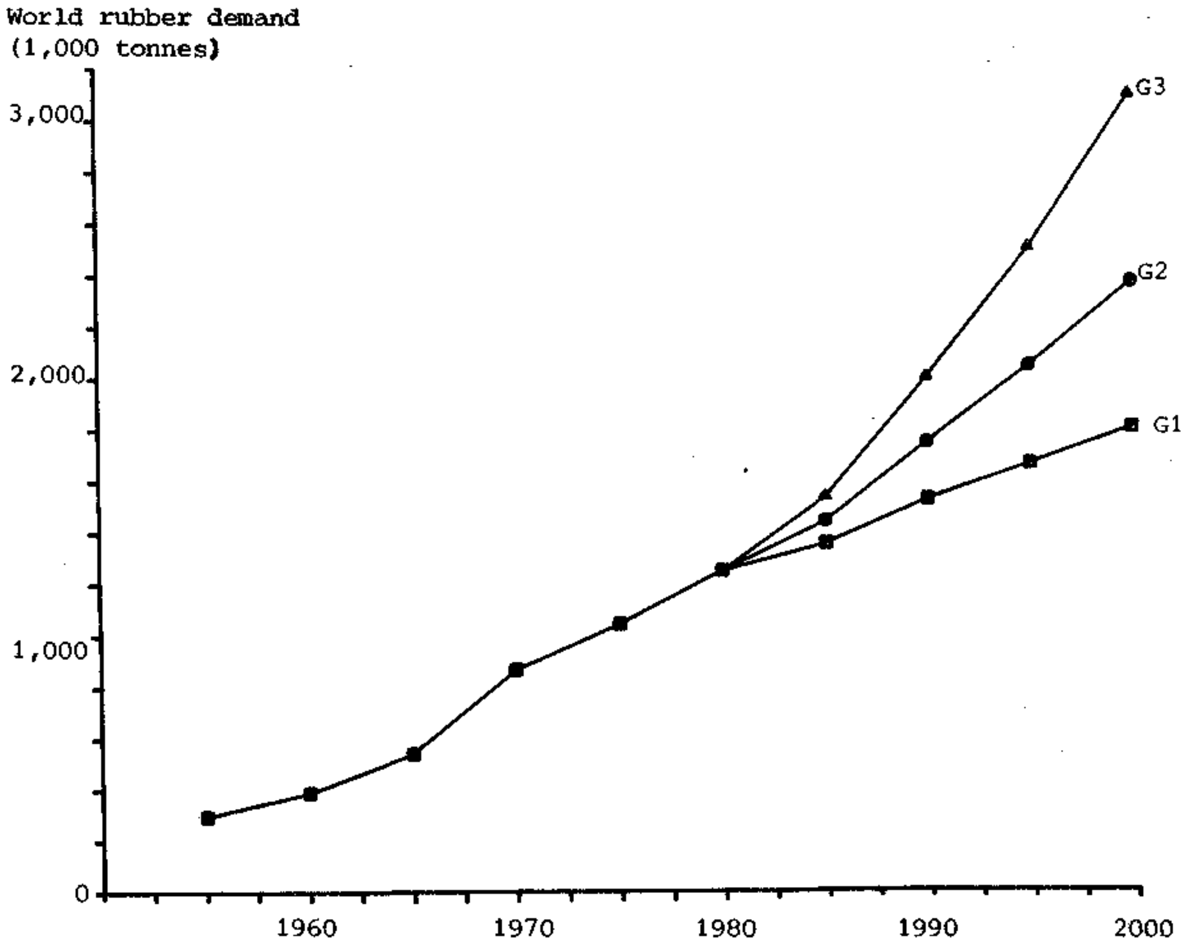


Figure 6.1 *Estimated and projected world rubber demand (in 1,000 tonnes), for 3 scenarios G1, G2 and G3*

7. NATURAL RUBBER SUPPLY: GENERAL ASPECTS

7.1 BROAD REVIEW OF TOTAL RUBBER SUPPLY

The ultimate objective of the study to which this chapter belongs, is to design an optimal production policy for natural rubber (NR) producing countries. Determination of such an optimal production policy has become increasingly difficult during the century long existence of NR production. In this chapter various aspects will be discussed which determine developments in NR production, be they an engine or an obstacle to growth.

Natural rubber can be extracted from numerous trees, plants, vines and shrubs. However, thus far only Hevea Brasiliensis and Guayule have been commercially produced in any quantities anywhere.

Hevea Brasiliensis has emerged as the major source of NR in the latter part of the 19th century and has maintained that position ever since. Hevea Brasiliensis is a tree from which rubber may be obtained by tapping i.e. controlled wounding of the tree, in particular the bark of the trunk. Hevea Brasiliensis enjoys a number of relative advantages such as high yield of latex during a sustained period and resistance to diseases and insect pests.

Guayule is a bushy perennial crop with an elaborate system of roots, allowing it to grow in rather dry areas. The plant grows best in well drained soils. Rubber constitutes 10-25 percent of the total (dry) weight of the plant, depending on the type. About two-thirds of the rubber is found in the stems and branches and about one-third in the roots. Rubber is obtained by either harvesting the plant including the roots, or by moving off the bushes about 5 cm above the ground. Most roots resprout and grow into new shrubs so fast that a thus developed one year old bush becomes as large as a two-year old seedling; in this way two crops are rapidly produced while avoiding the expensive replanting with seedlings normally required. It is unknown whether more than two crops can be produced in this way. In the early part of this century Guayule, only growing in Mexico (and some southern parts of the USA), accounted for some 10 percent of total world rubber production and some 50 percent of total US rubber consumption. In the 1920's Guayule was almost ousted because quantities of relatively cheap Hevea came on the market.

Large scale production of synthetic rubber (SR) emerged when, during the Second World War, supply of NR was insufficient, largely because of blocked supply-lines. Production of SR increased at that time particularly in North-America and Western Europe. To assure supply of rubber during the Second World War, many Guayule plantations were set up as well. Total production then amounted some 5,000 tonnes per year as a maximum. In the 1950's Guayule was outclassed by synthetic rubber.

In the fifties and sixties production of SR increased dramatically because demand for elastomers, particularly in the automotive sector, grew much faster than supply of NR, thus creating a reduction in the share of NR in total demand from 64 percent in 1955 to some 30 percent in the late seventies. This was feasible owing to technological improvements in SR, enabling SR to take over from NR. A major reason behind this development was lack of NR supply. There are various causes for the lack of growth in NR supply. They will be elaborated upon in section 7.4. Some data on consumption of rubber is presented in table 7.1.

Some synthetic rubbers have properties which are essential, or highly preferable, for some end-uses. A large part of SR, however, the general purpose synthetic rubbers, is in direct competition with NR for important end-uses. A surplus of NR and SR capacity to cover this type of demand will lead to a price decline for both types. In the past, this did not reduce current NR production, but led to idle capacity in the SR sector. A temporary shortage of general purpose rubbers will lead to a shift towards SR use, because SR capacity can be established in a few years, in contrast to expansion of NR capacity.

Supply projections of NR are themselves to some extent independent of future demand. As the share of NR in total demand is at present only 30 percent, whilst on technical considerations it could be much higher, a growth in NR supply outstripping growth of total demand is possible. This encroachment would lead to further price competition between NR and SR. Future development of production costs of both NR and SR will determine whether the price level of NR, resulting from this price competition, provides sufficient

Table 7.1 *World rubber consumption (in 1,000 tonnes) and NR market share*

	Total rubber consumption	*Natural rubber consumption*	*NR market share (%)*
1900	53	53	100
1910	102	102	100
1920	302	302	100
1930	722	722	100
1940	1,127	1,127	100
1950	2,339	1,750	75
1960	4,400	2,095	48
1970	8,625	2,990	35
1975	10,395	3,370	32
1980	12,445	3,760	30

Source: Rubber Statistical Bulletin
Allen, Thomas and Sekhar (1973)

incentive to expand NR capacity at a faster rate than the growth of total demand. The oil crisis of 1973-1974 and the subsequent increase in the price of oil, the major source of feedstocks of SR, has strengthened the position of NR.

Hevea, remaining the virtually exclusive source of NR, will its production in the future suffice to retain or even increase its share in total world rubber consumption? This will depend on the growth of NR production potential and, partially linked to this, on the relative prices of NR and general purpose SR's. Interaction between supply, demand and prices of NR and SR will be analyzed in chapter 9, while production potential of NR will be analyzed in chapter 8.

7.2 GEOGRAPHICAL DISTRIBUTION AND STRUCTURE OF THE NR INDUSTRY

Geographical distribution of world NR (Hevea) production

In recent years, from 1955 to 1980, world NR production has doubled. Geographical distribution of total production over the years is shown in chapter 8 . Since the end of the 1950's, with Malaysia being the leading producer, its share in world production increased from 36.4 percent in 1955 via 40.9 percent in 1970 to 44.0 percent both in 1975 and 1979. In 1980, however, it declined to 40.6 percent. Production in Indonesia declined to a minimum in 1960, recovered considerably in the following decade, remained on a plateau between 1970 and 1977, to grow fairly rapidly again after 1977. Thailand shows the fastest growth of all larger producing countries, its production practically quadrupled since 1955. Sri Lanka on the other hand, after some growth in the sixties, has remained stagnant until 1979. Her production declined in 1980 (and 1981). These four countries taken together accounted for 86.4 percent of world production in 1955, and 83.9 percent in 1980. Late-comers - and fast growers - are the Philippines and China. India has increased her share in world production from 1.2 percent in 1955, to 4.1 percent in 1980. The remaining countries only produced 7.3 percent of the world total production. The following paragraphs will concentrate mainly on the major producers: Malaysia, Indonesia and Thailand.

Structure of the NR producing industry

The most important aspect of the structure of NR producing industry is the size of the holding, represented by size of the area planted by rubber trees. Two groups can be distinguished: smallholdings and estates. The rationale for this division is the difference between the two groups in ownership, role of wage and salary earners, efficiency and productivity, access to markets and information.

In Peninsular Malaysia, the major area is taken up by smallholdings. However, this is a rather recent development. The decline of the rubber area of estates has been caused by transfer of area to other crops (e.g. palm oil) and fragmentation of estates into smallholdings. A major part, however, of the increase of smallholdings' area is due to new planting. A similar pattern can be recognized in Sabah, another part of Malaysia. The share of smallholdings in total area increased from 63 percent in 1961 to 84 percent in 1977. Sarawak, the third part of Malaysia, virtually only has rubber smallholdings; estates covered in 1962 only 2.3 percent and in 1977 only 1.5 percent of the total rubber area.

For Indonesia smallholdings already covered a majority of rubber land in the early sixties. Nowadays some 80 percent of total area consists of smallholdings. As was pointed out in a study by P.O. Thomas et al. (1976) on NR production in five major producing countries, most of the smallholdings are less than 3 ha in size, whereas many estates are over 3,000 ha in size. The larger part of the area under smallholdings is located in the South and the Centre of Sumatra and West Kalimantan. Estates are largely situated in North Sumatra and West Java.

Virtually all of Thailands rubber area can be found in South Thailand. In 1974 as much as 95 percent of the holdings was less than 40 ha, while a little less than 90 percent even had a size of less than 20 ha. The area under smallholdings in Thailand is even larger than in Peninsular Malaysia.

All other countries present a relatively more important estate sector than Thailand. Estates cover about 45 percent of the rubber area in Sri Lanka. More than half of the smallholdings area consists of holdings with a size of less than 4 ha. There is a tendency to call the medium holdings (4 - 40 ha) estates as well. A similar pattern can be seen in India. The number ot rubber growers was 132,000 out of which as much as 114,000 worked less than 2 ha. The total area under smallholdings (less than 40 ha) has doubled over the past two decades, now covering about 70 % of the total area. Except Nigeria, most other countries show a rubber sector which is predominantly estate oriented. For most of these countries, no recent reasonably accurate information on area under rubber is available.

Yield divergencies between countries and between the estate sector and the smallholders' sector

Data on area under natural rubber are not only scarce, but in some cases also unreliable. Moreover, the overall table in the Rubber Statistical Bulletin only indicates in a few cases what area is under high yielding, or under ordinary material; neither does it indicate what percentage of the area is immature, or very old and practically abandoned. Table 7.2 shows the total area under rubber for those countries for which data of rather recent years are available. Dividing production in the year of area registration by area gives an approximation of the average yield per hectare in each particular country or territory. In comparing average yields between countries, it must be remembered that discrepancies in area registration may have caused some distortion. Nevertheless the difference in yield per ha. between countries, shown in table 7.2 is so large that only a small part of it can be explained away by possible faulty area registration.

Table 7.2 *Average yields per hectare for selected countries or territories*

Territory	*Year*	*Total area* [1] *(hectares)*	*Production* [2] *(tonnes)*	*Average yield (kgs/ha)*
Peninsular Malaysia	1978	1,698,895	1,506,053	886
Sabah & Sarawak	1978	298,128	76,342	256
Indonesia	1977	2,327,591	835,000	359
Thailand	1974	1,404,160	379,489	270
Sri Lanka	1975	227,633	148,751	653
India	1978	235,910	132,991	564
Philippines	1978	53,700	56,600	1,054
Nigeria	1980	200,000	44,500*	223
Ivory Coast	1980	35,200	21,830	620

* estimate

Sources: Rubber Statistical Bulletin, Jan/Feb. 1982: 1) table 44; 2) table 5.

There are a number of reasons why productivity per ha. is higher in some areas than in others. It is generally assumed that climate and soil in West Africa are slightly less suitable for rubber growing than in South-East Asia. Thus the relatively new and well run NR industry in Ivory Coast nevertheless shows a lower yield than another new-comer, the Philippines. Obviously, new entrants do better than old established countries, as they are not burdened with areas under old trees with low yields. Yet there are also large differences in average yield between traditional rubber producing countries. A major reason for this is the structure of the industry, i.e. its division in estates and smallholdings. On the whole, estates can be expected to be better run than smallholdings, they will be the first to take advantage of new developments in breeding and maintenance of plantations.

From the point of view of technical possiblities there seems to be considerable scope for enlarging NR production in the next few decades, even without increasing the area or the number of people employed. Before returning to our basic question of sluggish NR supply in comparison to demand, a summary description of the entire process of producing NR will be given.

7.3 THE PRODUCTION CYCLE OF NATURAL RUBBER

Rubber planting and planting material

The immaturity period of a rubber tree is some 5 to 8 years. This implies that investment in rubber land remains unproductive for quite a number of years. To reduce this unproductive period of the land and to minimize the risk of seedlings not developing into proper rubber trees, nurseries have been established. They germinate the rubber seeds, which afterwards are planted in the ground and in polybags until they reach buddable size for green budding. By budding, optimal trees may be obtained consisting of two- or three-part trees. In case of a three-part-tree, the crown consists of planting material which is more resistant to leaf diseases. After harvesting the stumps by extraction, they can be planted in their places of destination, thus reducing the improductive immaturity period of the land by a few years. Improved agronomic practices, use of advanced planting material, disease and pest control and proper use of fertilizer can further reduce the immaturity period of the trees. An immaturity period of four years would seem to be the minimum.

A rubber tree is productive for 25 - 40 years. Maximum yield is reached around the tenth year of tapping. About ten years later a rapid decline in yield can be observed. This requires the area to be replanted at a certain moment in time depending on whether a tree is still called productive or not, in relation to expected productivity of the replacing tree.

On estates, replanting can be done on a percentage basis, thus constituting an annually recurring cost. Smallholders, however, usually have to replant in one go with the concomitant loss of income. Therefore, they tend to postpone replanting as long as possible, thus reducing average yield and incomes. In many countries a system of replanting grants is (being) set up. An additional source of income during the immaturity period may be derived from intercropping e.g. with vegetables.

Studies on the optimum replanting age of rubber trees have been done among others by Ismail (1969), Ng Choong Sooi (1972) and Etherington (1977). Conclusions drawn by Etherington are that the efficient set of replacement dates is very wide because of the difference in efficiency and yield between estates and because discounted net revenues are not very sensitive to choice of replacement date.

Hevea clones are different with respect to a variety of factors:

- average yield
- length of period of yield
- early yield
- wind susceptibility
- disease and pest resistance
- soil and terrain requirement;

In general, high yielding trees are more risk prone. For estates, a mixture of clones is recommended, while recommendations for smallholdings depend on the size of the holding, because of risk aversion and long-term secured income. Besides, by budding, combinations of clones can be formed, thus e.g. providing a tree with a high-yielding trunk and a crown which is more resistant to leaf diseases.

In general, clones may be divided into ordinary material, mainly derived from seedlings, and high-yielding material. Estimated yield per year of tapping for a few groups of high-yielding clones is given in table 7.3. The estimates were made by the Rubber Research Institute of Malaysia and presented in Association of Natural Rubber Producing Countries (1976). Clonal seedlings may yield about half of these and unselected seedlings will yield even less.

Tapping, stimulation and field upkeep

Tapping a rubber tree is essentially a process of controlled wounding of the tree. The severing of latex vessels in the bark will lead to production of latex. By removing a small slice of bark, the latex will start flowing. By using a sloping cut the latex will flow along the cut into a latex cup attached at the end. To obtain good yields the tapper must cut to within one millimetre of the cambium, where the largest number of latex vessels is located.[1)] Shallow tapping will considerably reduce output.

An alternative to the above tapping method is not to remove a small slice of bark but to make small holes in the bark through which the latex will start flowing. This method is still in the experimental stage. It is less labour-intensive and does not consume bark. However, yields are lower as well.

1) An elaborate description of many aspects of rubber production can be found in Pee T.Y. and Ani bin Arope (1976), which also has been the main source for this section.

Table 7.3 *Yield profiles of some of the popular clones (in lbs per acre)*

Year of tapping	*RRIM 600 PR 225 PR 261*	*RRIM 527 AVROS 2037*	*GT 1 PB 28/59*	*RRIM 703*
1	981	446	758	758
2	1,204	714	1,026	1,338
3	1,428	981	1,517	1,784
4	1,651	1,294	1,651	2,052
5	1,561	1,561	1,829	1,695
6	1,874	1,294	1,874	2,052
7	2,097	1,606	2,097	2,141
8	2,007	1,383	2,052	2,320
9	2,097	1,472	2,007	2,632
10	1,918	1,472	2,052	2,409
11	2,855	2,498	3,078	3,569
12	2,721	2,677	3,346	3,390
13	2,543	2,409	3,033	3,212
14	2,186	2,141	2,097	2,766
15	1,918	1,963	1,918	2,409
16	2,320	2,587	2,543	2,900
17	2,097	2,231	2,141	2,587
18	2,141	2,097	2,007	2,677
19	1,849	1,784	1,740	2,320
20	1,643	1,606	1,651	2,141
21	2,543	1,829	1,918	2,231
22	2,007	1,472	1,606	2,052
23	1,918	1,383	1,428	1,563
24	1,784	1,294	1,338	1,784
25	1,561	1,115	1,160	1,517
26	1,561	1,115	1,160	1,517
27	1,740	1,249	1,294	1,695
28	1,561	1,115	1,160	1,517
29	1,294	937	981	1,338
30	1,294	937	981	1,338

Source: Association of Natural Rubber Producing Countries (1976).

Stimulation of trees to increase yields has been tried for a long time. Some growth substances were found to produce ethylene in plant tissues. Ethylene causes a delay in the plugging of the latex vessels. The time of latex flow is extended. Experiments, conducted by the Rubber Research Institute of Malaysia, showed that Ethylene gas when applied directly to the tree, can double the yield. Ethrel or Ethephon, an ethylene releasing chemical, was found to be highly effective. It is applied to the tree monthly or bimonthly between May and December either to the panel above the tapping cut or to the groove of the tapping cut or to the bark below the tapping cut (panel: barkless part of the trunk). Until now it has been advised to apply Ethrel stimulation only on renewed bark, that is after about 10 years of tapping, and with less than a 100 percent intensity of the tapping system,

The increase in yield is one aspect of stimulation. Another aspect however is increased flexibility of production. This kind of flexibility was taken advantage of in 1975 when rubber prices dropped sharply. A ban on Ethrel usage by the Malaysian Government reduced estate acreage under Ethrel stimulation by some 50 percent. Consequently rubber production by estates declined from 659,520 tonnes in 1974 to 580,759 tonnes in 1975.

A further advantage of stimulation and the related increase in flexibility is that other tapping systems may become more profitable. An increase in profits may then be possible through cost reduction rather than production increase.

A rubber tree does not require the most fertile area of the country. On the contrary, the tree is satisfied with reasonable physico-chemical and morphological characteristics. However, very sandy, structureless soils must be avoided, as well as silty clay soils. A deep good structured friable soil is desirable. A tropical climate is necessary for rubber growing. One of the most northern areas where Hevea rubber is successfully produced, is the Chinese island Hainan, 19° North of the equator. Current trials in the North-East of Thailand (14° N) show yields which are very promising, though lower than in the South of Thailand. In general, application of fertiliser is necessary to obtain a satisfactory yield.

Processing and grading of NR

The latex that comes out of the rubber tree is unstable and must be processed soon after collection. Next to latex some residual scrap is collected. Both latex and scrap need to be processed in order to obtain a commodity which can be marketed and shipped. Broadly, there are four final forms of the commodity

- sheet rubber
- latex concentrate
- crepe rubber
- block rubber.

Each of them will be discussed briefly.

Traditional forms of processed rubber were packed in large bales of 200 lbs and were graded visually, which, of course, created a lot of problems. To overcome these problems block rubbers are produced by initially blending the raw material collected from various sources in tanks. Thus uniform and consistent grades of rubber can be produced to meet specific market needs with respect to e.g. chemical additives. Many countries have these kinds of technically specified rubbers (TSR) e.g. Malaysia (SMR), Indonesia (SIR), Thailand (TTR) and Sri Lanka (SLR). After coagulation, the coagulum is cut into crumbs which then are dried by hot air and baled using polyethylene bags weighing 70 lbs.

There may be market quotations for some of the above types of NR, spot and futures on the major NR markets, London, New York, Singapore and Kuala Lumpur as well as on more locally oriented markets in other cities. Because the various types are not full substitutes of each other particularly in the short-run, owing to rigidity of the production processes, price behaviour may be partially independent between types of NR. The major types are RSS1, RSS3 and block rubbers.

Production costs

Total production costs can be split into investment costs and running costs. The first category consists of field establishment, buildings and machine and vehicle park, the second category includes payment for all services and materials required to keep the estate and its factory running. Elaborate information can be found in Pee T.Y. and Ani bin Arope (1976), Maria J. 't Hooft (1978) and Pee T.Y. (1982).

Relative importance of cost factors

To estimate the influence of various cost elements on investment decisions in NR, Maria 't Hooft (1971) introduced the concept of full supply prices. The full supply price is the price which, if received over the entire lifetime of the estate, would just equate the present value of all expenditures to the present value of all receipts.

In an as yet unpublished World Bank paper, T.Y. Pee (1982) has estimated full supply prices for various types of NR in 1979, for an estate of 1,000 hectares in Malaysia with an average annual production of 1,776 kgs/ha. His findings for an estate producing various types of ribbed smoked sheets are reproduced here in table 7.4.

It becomes immediately clear that the rate of interest (used as discount rate in a discounted cash flow calculation) is of paramount importance. During the immaturity period, large capital expenditures have to be made, which are not yielding any receipts for some 4 to 6 years. The effects can be seen especially on the first three items in table 7.4 , and to some extent on "Management and other overheads", which relates only partially to the immaturity period. A higher interest rate, by making investment costs per kg much higher, thus requires a higher NR quotation to induce investments. But this is only part of the story. As in Malaysia both basic wage and tappers' bonuses, and the export duty, are related to the RSS1 market quotation, the higher supply price required at higher interest rates also induces higher wage costs (items 5, 6 and especially 7 in table 7.4) and a very steep increase in export duty.

It should be mentioned here that in a discounted cash flow analysis the discount rate used should be the real rate of interest, i.e. the nominal rate of interest minus the current inflation percentage. An eight percent real discount rate should therefore already be considered as very high. Table 7.4 shows that, if average expenditures on a 1,000 ha estate in Malaysia have been estimated correctly, it would have been worth-while to invest in such an estate in 1979 if the RSS1 quotation were expected to be 192.8 M¢/kg or over in the future, for this price would cover all the expenditures required to produce a mixed bag of ribbed smoked sheets and earn a real interest of eight percent on all capital invested. (The RSS1 quotation has to be higher than the supply price, because lower grade RSS, which also has to be

Table 7.4 *Composition of supply prices for a 1,000 ha estate in Malaysia, producing ribbed smoked sheets, at various real discount rates, in 1979*

Item	*Costs (M¢/kg) at various real discount rates*				*Percentage distribution of costs*			
Discount rate	*0*	*4*	*8*	*12*	*0*	*4*	*8*	*12*
1. Field establishment	8.5	16.4	29.0	47.4	7.7	12.3	15.6	17.7
2. Investment in RSS factory	2.6	4.0	5.6	7.4	2.4	3.0	3.0	2.8
3. Other investment expenditure	8.1	12.7	19.2	28.1	7.3	9.5	10.3	10.5
4. Management and other overheads	15.4	17.5	20.9	25.5	13.9	13.1	11.2	9.5
5. Fringe benefits	15.3	15.7	16.4	17.3	13.8	11.7	8.8	6.5
6. Field production costs	17.1	17.8	18.5	19.3	15.5	13.3	9.9	7.2
7. Tapping costs	26.9	31.4	40.7	46.7	24.3	23.5	21.9	17.4
8. Processing charges	8.4	8.4	8.4	8.4	7.6	6.3	4.5	3.1
9. Total production costs	102.3	123.9	158.7	200.1	92.6	92.6	85.3	74.6
10. Fob. charges	6.0	6.0	6.0	6.0	5.4	4.5	3.2	2.2
11. Research cess	2.2	2.2	2.2	2.2	2.0	1.6	1.2	0.8
12. Export duty	-	1.7	19.1	60.0	-	1.3	10.3	22.4
13. Supply price	110.5	133.8	186.0	268.3	100.0	100.0	100.0	100.0
14. Equivalent RSS1 quotation	117.3	140.6	192.8	275.1				

Source: T.Y. Pee, Supply and cost prices of rubber production
World Bank, Washington DC, 1982.

produced, receives a lower price). The average RSS1 quotation in Malaysia in 1979 was 279.4 M¢/kg and thus well above the supply price at 8 percent real discount.

This conclusion, however, only holds if all expenditure items, especially wages, were expected to rise in future in exactly the same way as prices of NR, in other words if the rate of inflation were the same for both costs and prices of NR. It seems likely that this expectation was not valid in Malaysia in recent years. The spectacular growth of the country, resulting in a labour shortage, may have led to expectations about rises in real wages exceeding a possible rise in future NR prices, thus requiring a higher supply price than indicated here.

It is unfortunate that the same type of studies about supply prices as mentioned above, has not been undertaken for other NR producing countries. They differ from Malaysia both in costs, especially wage levels, which are much lower, and in yields, which are also much lower on the average. New plantings and improvements in management could however be expected to result in levels of yields comparable to those in Malaysia. Wages on the other hand, especially in Indonesia and Sri Lanka, cannot possibly reach Malaysian levels within the next few decades. It may therefore be assumed that a supply price which would induce investment in NR in Malaysia is amply sufficient for the other major NR producers.

7.4 OBSTACLES TO GROWTH OF NR PRODUCTION

Considering the fairly substantial macro-economic benefits which countries have derived from their NR industry, it may seem surprising that the overall supply of NR since World War II could not keep pace with the increase in total demand for rubbers. There are however a number of reasons, both at the macro and micro level, that can be identified as obstacles to growth. They are of a political, economic and organizational nature.

Reviewing increases or reductions in production of various countries over the years, immediately shows up those countries where war or severe internal political unrest, led to stagnation or decline of the industry. It is hardly surprising that e.g. the formerly flourishing NR industry in Vietnam has fallen on hard times. An other political factor that has negatively influenced especially new or replanting by estates was the uncertainty about the future status of foreign estate companies in some countries.

Even if there was only talk of nationalization in the future, new investment in the crops with a long immaturity period may have seemed hazardous to foreign owners. This may to some extent have been the case in Sri Lanka. In Indonesia, where nationalization became a fact early in the period under consideration, the lack of expertise enhanced the general unfavourable effects of unstable government. Only around 1965 did Indonesian production pick up again.

When considering the obstacles to growth of an economic nature, it is useful to distinguish between estates and smallholders, and to consider the period up to the first oil crisis, and the following years.

The case for estates

Increases in supply may result from an increase in yield per hectare or an expansion of the area under rubber, or both. Although some increase in yield per hectare is feasible through better management, really worth-while yield improvements can only be obtained through the planting of new high yielding clones. This requires a major investment decision, of which the elements are described in section 7.3. Expectations of future prices must be such that heavy investment costs, and running costs for the next thirty years, are likely to be recovered. On the one hand there is the strong incentive that replanting to high yielding clones will double or even triple yield per hectare. On the other hand, the steady decline of rubber prices in the sixties was not conducive to the expansion of NR production.

Since the second half of the 1950's, the SR industry not only spread from the United States to Europe and Japan, but also vastly improved its methods, products and scale. This gave rise to enormous economies of scale during that period. As during the same time the price of crude, the base of feedstocks for the SR industry, declined in real terms, and competition between the major SR companies was fierce, the trend of general purpose synthetic rubber prices was severely downward.

Although some NR is essential for some end-uses, it could be replaced, especially by SBR, in a great many others. The supply of NR, although growing much more slowly than for rubbers, was still always larger than the amount required for those end-uses where it was irreplaceable. NR therefore had to be price competitive with SBR, in the sense that it could only be a few cents per kilo more expensive than SBR 1500. The decline in the NR price from a 100-base in 1955/59 to an ultimate low of 44 in 1972 thus is a faithful replica of the reduction in production costs of its major competitor SBR. It needs hardly be said that this downward trend of nominal prices was even much more severe in real terms.

Of course, the period from 1955-73 also showed some upward price fluctuations, due to boom periods especially in the automotive industry, when even SR producers reached full capacity. The ensuing expansion of the SR industry, which only takes a few years, then sufficed for all rubber prices to resume their downward trend again. The fact that during this period world production of NR doubled, and in some countries even tripled or quadrupled, shows the enormous resilience of the NR industry.

Section 7.3 has described the improvements in planting material, reached in research stations, resulting in clones reaching an average of some 1500-2000 kgs/ha over their entire life-time. Coupled with new methods of stimulation and general field maintenance, these developments were apparently sufficient to induce estates to replant even during the 1960's. Yet to keep a rubber estate profitable in the face of ever declining prices must have been uphill work. It is therefore not surprising that during this period the estate area under rubber in e.g. Malaysia declined by some 20 percent.

After the oil crisis of 1973 the outlook for the NR industry became quite different. Not only had the curve of declining costs in the SR industry, due to economies of scale and technological improvement, flattened out considerably, but the sudden hike in feedstock prices pushed production costs sharply upward. Table 7.5 shows the RSS1 quotations in London from 1970 to 1981, and also the UK list prices for SBR 1500/2 during the same period.

It should be remembered that SR is not necessarily sold at list prices. Depending upon the existence of overcapacity, discounts of up to 30 percent may be given. The list price however is strongly related to production costs plus a profit margin; its increase from 1973 to 1974 is staggering. Another steep rise is very evident in 1979/80 at the time of the second oil crisis.

Table 7.5 *RSS1 quotations in London and UK list prices of SBR 1500/2*

Year	*London RSS1 (c.i.f.) £/tonne*	*Index 1970 = 100*	*UK list prices SBR 1500/2 £/tonne*	*Index 1970 = 100*
1970	180.4	100.0	165.00	100.0
1971	143.7	79.7	174.50	105.8
1972	147.7	81.9	176.75	107.1
1973	300.2	166.4	197.00	119.4
1974	342.2	189.7	347.00	210.3
1975	287.5	159.4	386.25	234.1
1976	475.0	263.3	419.50	254.2
1977	508.6	281.9	496.00	300.6
1978	552.7	306.4	545.00	330.3
1979	638.2	353.8	617.75	374.4
1980	663.0	367.5	697.00	422.4
1981	557.0	308.8	749.00	453.9

Source: Rubber Statistical Bulletin, Jan/Feb. 1982, tables 42 and 43.

The presentation in table 7.5 , where the London quotation of RSS1 is shown in sterling, however, hides the fact that the increase in these quotations also reflects the depreciation of sterling in comparison to the Singapore dollar and the Malaysian ringgit. In comparison to exchange rates in 1970 the Singapore dollar had in 1981 appreciated by nearly 45 percent over the US dollar and even by 57 percent over sterling. The Malaysian ringgit, which was at par with the Singapore dollar in 1970, showed a discount of nine percent under the Singapore dollar in 1981. Nevertheless this means that the ringgit has also appreciated considerably in comparison to the US dollar and sterling.

For a NR growing country like Malaysia two contrasting influences therefore have been at work during the seventies. On the one hand, the rise in oil prices increased the production costs of competing synthetic rubber. On the other hand, the appreciation of its currency made its products, and therefore its natural rubber, less competitive in the outside world. As has been shown in section 7.3; investment in rubber trees, producing on average 1,776 kgs/ha, would still have been quite remunerative under Malaysian cost conditions in 1979, at the then prevailing NR quotation. However, NR prices have come down considerably since then. It can of course be argued that prices in 1981 and 1982 have been abnormally low because of world recession, but as nobody is very sure if and when an economic revival will occur, the investment incentive to estates calculating in Malaysian or Singapore currency is at present certainly nil.

Even when prices were to recover to their 1979 level, investment in NR for estates would only be justified at a high yield level and about the same labour costs. The latter however seems unlikely. From International Financial Statistics it can be calculated that GDP/*capita* in real terms increased annually by 6.6 % in Singapore and by 5.2 % in Malaysia between 1970 and 1980. This very fast growth has not only nearly doubled the personal income of their population, but has also led to a scarcity on their labour markets. There is every reason to suppose that this will make estate labour even more scarce and expensive in Malaysia than it already was in the latter half of the 1970's.

Whilst the ever-declining price trend of NR in the 1960's induced estates to switch from rubber to palm oil when replanting, the growing labour shortage and strong rise in wages in Malaysia has resulted in the same move out of rubber in the second half of the seventies. Palm oil, one of many competing edible oils, has a fairly steady price that is apparently high enough for the very efficient Malaysian producers to receive a satisfactory return on investment. An additional advantage is that palm oil, being refined domestically, is then regarded as an industrial product and therefore does not carry an export tax. Natural rubber, regarded as a primary commodity even in the form of crumb rubber, faces a steeply progressive export duty. Although the Malaysian government adjusts export taxes from time to time, to compensate for the incidence of inflation and higher real wage levels, these adjustments lag considerably behind nominal cost increases. There is therefore a strong inducement for estates in Malaysia to move from rubber into palm oil.

New planting and replanting of rubber on estates in Malaysia would therefore only be likely to occur on a large scale if one or more of the following requirements were fulfilled:

- if new clones were bred with a yield considerably higher than those in existence. Although some improvement in yield is still possible in Malaysia, it will not be as spectacular as in the fifties and sixties;

- if new tapping methods were developed that were to make the industry less labour-intensive;
- if in future real wages increased no faster than the increase in productivity per ha. It seems likely however that real wages will increase more rapidly, and that gains in labour productivity through mechanization and new tapping methods may just about keep costs at the same level in real terms;
- if the government saw fit to reduce export duties or better even to abolish them;
- if oil prices again were pushed upwards in real terms, thereby making synthetic rubbers uncompetitive;
- if the Malaysian and Singapore currencies did not continue to appreciate in terms of most Western currencies. As Malaysia steadily increases her oil exports, her balance of payments situation in the longer run seems fairly healthy, and not likely to give rise to devaluations.

For Indonesian estates, the outlook seems quite different. Although on Java some old, decrepit estates seem to be replanted to food crops, the other islands still offer large scope for improvement of old estates, or establishment of new ones. Yield per ha in Indonesia is less than half the Malaysian figure. This cannot be attributed to disadvantages in climate or soil. Replanting only got under around 1965; there is still a considerable lack of staff able to implement modern rubber growing methods.

There is no overall labour shortage in Indonesia, on the contrary the numbers of unemployed or underemployed are still very large. (Labour may however be at the wrong place, vide the transmigration schemes that Indonesia is executing at present.) Wages are very low in comparison to Malaysia. GDP per capita has grown between 1970 and 1980 at an annual rate of 4.9 percent; however, this very healthy growth has not reached large sectors of the population, who remain desperately poor. It would seem possible, at foreseeable wage rates, using modern clones, with average management standards, to run estates profitably in Indonesia even at 1982 very low rubber prices.

However, this overlooks the comparative lack in Indonesia of those facilities that are abundant in Malaysia: proper roads and waterways, agricultural research and extension services, staff training and perhaps above all finance. It is not sufficient to know that an estate, if properly planted to modern clones, would be profitable; the funds necessary to cover the immaturity period have to be there. It may therefore take another decade for Indonesia to organize all these different aspects in such a way that the rate of production growth, prevalent in Malaysia between 1955 and 1970, would be reached.

The case for smallholders

It has already been indicated that in all NR growing countries smallholdings have a lower yield per ha than estates. This need not however mean that a rubber smallholder leads a life that is materially worse than that of an estate tapper, unless his holding is very small indeed, or unless he suffers from very onerous tenancy conditions.

There is however one difference between estates and smallholdings that forms an obstacle to future productivity increases. It is one thing for a young man to get out, clear a patch of jungle, and plant a rubber garden. For an established smallholder to cut down his entire holding, replant, and wait for 5 or 6 years until the new trees are yielding again, is a quite different effort. Estates are large enough to be replanted in batches of a few hectares; it is impossible to replant a smallholding in small batches. The smallholder thus has the choice of going on tapping his (too) old trees, or to make the superhuman effort of saving enough to keep his family during the entire immaturity period.

In the traditional NR growing countries most trees were obsolete by the end of World War II. In the fifties the Malaysian government was very much aware of the difficulties for smallholders to replant. A scheme was introduced whereby the entire smallholders' area paid for replanting the area bit by bit. A replanting cess was levied on all exports of rubber, and repaid to estates, but used by the authorities to finance the replanting of part of the existing smallholdings each year. Part of the replanting grant was paid in kind - good planting material, fertilizers -, part was a cash grant which originally was large enough to provide a minimum livelihood. As can be seen in table 8.2, replanting by smallholders proceeded steadily, only faltering a bit in the second half of the 1970's. This may have been caused by the replanting grants becoming too low in view of the overall rise in living standards; in any case replanting grants were increased in 1981 by 67 to 83 percent, depending on the size of the holding.

(Moreover, to owners of holdings below 4 hectares, additional monthly financial assistance is given, repayment of which will begin when the newplanted trees mature.) Next to the replanting schemes, some Government Agencies have opened up new land for smallholders. Some of these schemes are more-or-less run on an estate basis, although the settlers are owners of the land, thus improving yield per hectare.

The result of these efforts - in combination with excellent extension services - is that in 1981, according to the Bank of Malaysia, 90 percent of smallholders' area is under high yielding trees (yield in 1980 was 814 kg per mature hectare).

That concentrated efforts to rejuvenate the smallholders' sector can show big results, is borne out by the increase in smallholders' production from 294,303 tonnes in 1960 to 594,755 tonnes in 1970, representing an annual rate of growth of 7.3 percent. From 1970 to 1980 however, this annual growth was only 3.9 percent (from 594,755 tonnes in 1970 to 877,090 tonnes in 1980). This lower growth rate in the seventies is entirely due to smallholders' production becoming stagnant in 1976, and even declining in 1980.

It would seem from the drastic increase in replanting grants that the Malaysian government intends to go on improving smallholders' yields. Whether these measures will be sufficient to stem the flight from the land, especially if prices continue to remain as low as at present for some more years, remains to be seen.

In Thailand, where nearly all production originates from smallholdings, improvements in husbandry have been going on steadily. This has no doubt been aided by the existence of a FAO/UNDP research station. Production increased by an average annual rate of 5.5 percent between 1960 and 1980. Yields per hectare also increased, but are still at a very low level in comparison to Malaysian smallholdings (in 1978 the average yield was 315 kgs/ha). In the 1960's replanting happened only occasionally because of lack of funds and uncertainty about titles to the land. In the seventies however the World Bank provided considerable loans for this purpose, which in combination with government efforts will no doubt show results in the eighties.

In Indonesia the average yield of smallholders is as low as in Thailand, and its growth has been slower, at an average annual rate of 2.5 percent between 1960 and 1980 (see table 8.6) . Yet the smallholders' sector has done much better in these years than the estates' sector where growth was only one percent a year on average.

Both in Indonesia and Thailand therefore scope for increased production seems large, were it only through increased yields. The organizational problems however, especially in Indonesia, are awe-inspiring, and the funds required for the necessary replanting are vast. The realization of a higher growth rate, especially in Indonesia, therefore would seem to depend on the willingness of government to spend large amounts of finance and efforts on the rubber sector. This in its turn will depend on the government's appraisal of the outlook for NR in the future.

NR's share in world rubber consumption in the future

Table 7.1 has shown NR's share in world rubber consumption declining over the years. It should however be remembered that overall rubber consumption has been growing very fast in the past. Between 1960 and 1970 total consumption increased by 8.3 percent a year; in the 1970's this growth averaged 3.7 percent a year. It is of course understandable that any agricultural production cannot keep pace with a consumption growth of over 8 percent a year, so that in the fifties and sixties the share of NR in total rubber consumption simply had to fall, even if there had been no political obstacles to production growth.

At the same time however it has been shown that NR production can grow relatively fast (7.3 percent for smallholders in Malaysia in the sixties and 5.5 percent for smallholders in Thailand in the last two decades) when sufficient agronomic guidance and replanting funds are provided. Especially Indonesia and Thailand, both large producers with an as yet low yield per ha, could increase production considerably. This might (over)-compensate a possible decline in Malaysia, if the overall growth of her economy remained so buoyant that labour scarcity would lead to a decrease of NR production.

8. ANALYSIS AND PROJECTIONS OF NATURAL RUBBER SUPPLY

Introduction

The purpose of this chapter is to obtain projections, but, also, to analyze supply in relation to
- new planting
- replanting
- technical developments.

The ultimate objective of this study is to arrive at suggestions for a long term production policy that will optimally meet demand fur rubber. Total demand for rubber has been derived in chapter 6. Interaction between supply and demand of NR and SR will be studied in chapter 9, after which conclusions can be drawn about an optimal production policy for NR. In this chapter analyses will be undertaken at a country level, insofar as that is possible and necessary.

8.1 MALAYSIA

General aspects

Rubber is grown both in Peninsular Malaysia and in East-Malaysia i.e. Sabah and Sarawak. Because of important differences in the structure of the industry as well as in availability of data, the situation in the two regions will be analyzed separately.

Peninsular Malaysia

Rubber production in Peninsular Malaysia can be divided into estate production and smallholder production. Estate production has grown from about 360,000 tonnes in 1956 without interruption to 660,000 tonnes in 1971 and has stagnated or even decreased ever since with lows of 580,000 and 593,000 tonnes in 1975 and 1981, respectively (see table 8.1). Among the reasons for the growth in the sixties were dramatic replanting as well as new planting in the fifties and first part of the sixties (see tables 8.2 and 8.4 for more details), the yield of which was much higher than that of the trees that were replaced. Besides, application of fertilizers and stimulants further increased the yield.

Table 8.1 *Production of NR in Malaysia (1,000 tonnes)*

	Peninsular Malaysia			*East-*	*Grand*
	estates	*smallholdings*	*total*	*Malaysia*	*total*
1955	358.2	290.8	649.0	60.3	709.3
1956	357.2	278.8	636.0	61.6	697.6
1957	374.5	273.2	647.7	61.8	709.5
1958	396.4	277.1	673.5	60.1	733.6
1959	414.5	294.5	708.9	67.4	776.3
1960	420.7	299.0	719.7	72.8	792.5
1961	435.4	311.0	746.4	68.3	814.7
1962	445.3	316.2	761.5	56.9	818.3
1963	465.7	333.6	799.3	65.8	865.1
1964	484.5	352.9	837.4	66.8	904.2
1965	498.8	385.5	884.3	64.9	949.2
1966	522.1	418.1	940.2	58.1	998.3
1967	534.2	411.5	945.8	52.3	998.1
1968	572.1	479.2	1,051.3	49.0	1,100.3
1969	603.0	596.5	1,199.4	68.6	1,268.0
1970	621.0	594.8	1,215.7	53.5	1,269.2
1971	661.6	608.9	1,270.4	48.1	1,318.5
1972	659.3	598.8	1,258.1	46.2	1,304.3
1973	673.6	791.5	1,465.2	77.2	1,542.3
1974	659.5	801.0	1,460.5	64.2	1,524.7
1975	580.8	817.5	1,398.3	61.0	1,459.3
1976	651.7	884.5	1,536.3	76.1	1,612.4
1977	627.6	883.9	1,511.6	76.4	1,588.0
1978	618.0	888.0	1,506.0	76.3	1,582.4
1979	607.3	890.1	1,497.3	71.8	1,569.1
1980	609.1	877.1	1,486.2	66.0	1,552.2
1981	593.3	881.9	1,475.2	52.0	1,527.6

Source: Rubber Statistical Bulletin (IRSG).

Because of continuing decrease of natural rubber prices in the sixties (cf. table 1.1), there was a tendency to replant with other more profitable crops such as palm oil. The resulting decrease in area is the major cause for stagnation in estate rubber output. The production decline in 1975 largely originated from the fall in prices and was partly engineered to support prices.

On the smallholder side, growth in production started later because new planting and replanting only gained momentum in the sixties and therefore started to be of influence on production in the late sixties. This created a boom in production in the late sixties and in 1973 and 1976, especially because of then prevailing high prices. Production increased 16.5 percent in 1968, 32.2 percent in 1973 and 8.2 percent in 1976. Since 1976 there has been no increase in production and a level of slightly less than 900,000 tonnes was maintained.

A decrease in NR production can be seen in 1980 both in the estate- and the smallholder-sector. This happened in spite of trebling nominal prices compared to the early seventies reaching a high of M$ 3.69 per kg for RSS1 as an average in February 1980, and remaining in the M$ 3.00 range throughout 1980. A further decrease in production is seen in 1981, largely caused by a reduction in NR prices by about 40 percent.

A major reason for this stagnation and even decline in production was the limited availability of labour. For a national figure some estimates give a 3 percent labour shortage in 1979 and a 6 percent labour shortage in 1980. Hardest hit are states which are close to growing industrial zones, such as Johore and Pahang, close to Singapore. The dramatic boom in construction and other industrial activities both private and public and both in Malaysia and Singapore have attracted many Malaysian estate workers as well as smallholders. The response of estates may partially be a switch to other crops. Palm oil may be a choice, although palm oil prices have decreased recently as well. Another way out seems the hiring of foreign guest workers e.g. from Indonesia. Some sources estimated their number at 100,000 in 1981, although a majority of them as yet has no legal status. Measures to improve the situation are taken.

On the smallholder side, there is a tendency to abandon (old) rubber land in exchange for a job in urban areas. This seems to be caused by the relative quality of labour conditions as well as by what may be indicated as the "bright lights" of "industrial and town life", rather than by income and cost differentials. In many cases parents are left with the smallholding. While receiving remittances from their children they may tap at a lower frequency. The situation to date, October 1982, seems even worse. Prices of NR have remained at the low level that was reached in late 1981. This certainly stimulates even more rubber workers to move to other jobs. Because of recession in consuming countries, combined with extremely high interest rates, causing consumers and related dealers to keep their stocks at a minimum, physical demand reaches a short-term low. Uncertainty about the future dramatically reduces buying. The buffer-stock manager of the International Natural Rubber Organization has actively bought a large amount of rubber to support the price.

Although there is no proof for this as yet, it is beyond doubt that the switch from rubber to industry for most people will be irreversible. A labour shortage of more than 6 percent can therefore be envisaged. This will in the short-run affect production whereas in the long run it may reduce new planting and cause replanting with rubber giving way to replanting with other crops.

Yet it would seem to be wise to replant at the current low price, because the revenue lost will be small and a reduction in supply might support prices, if it is agreed that the long-term prospect of NR is bright and that there is very little chance for NR supply to exceed NR demand even if new planting, replanting and rehabilitation would drastically increase NR production potential. It is the purpose of this study to clarify the future for NR and to indicate which production potential is optimal. Conclusions will be drawn in chapter 9.

East-Malaysia

The situation in East-Malaysia is completely different. Production is not very stable over time, as can be seen from table 8.1 and is distributed rather evenly between Sabah and Sarawak. Production per hectare on average is only 30 percent of production per hectare in Peninsular Malaysia. This is partly due to untapped area because of scarcity of tappers on estates at Sabah. The area of estates at Sabah has decreased by about 50 percent since the late sixties and now amounts to about 15 percent of total area at Sabah. Almost all rubber area at Sarawak is owned by smallholders. The percentage tapped is very low for smallholders both at Sabah and Sarawak. This can be ascribed to low productivity, low farmgate price and availability of other sources of income.

Peninsular Malaysia, smallholdings model

Smallholders' rubber production has tripled between 1959 and 1976. In the same period planted hectareage only increased by just over 40 percent. Productivity increases largely originate from shifts to higher yielding trees. It is therefore very important to include the year of planting in the analysis. Besides, as has already been mentioned in chapter 7, the age of the trees is very important; immature trees are not productive and trees will produce less when they grow older. Summarizing, to analyse the effects of new planting and replanting, immaturity periods and shifts to higher yields must be included. It is for these reasons that a vintage approach has been pursued. The following aspects have been investigated:

a. area distribution by vintages
b. yield profiles
c. technical progress
d. production.

At the end of this chapter projections of NR production for various systems of new planting and replanting are derived and assessed.

a. Area distribution by vintages
Discarding systems

Reasonably adequate data on area distribution by vintages, i.e. the number of hectares planted in year τ and still existing in year t is not available for a proper period of time which might act as the period of analysis e.g. t = 1955, ..., 1980. Of course these data might be calculated if the distribution in the starting year 1955 was known and if discarding of trees was given by vintage. Unfortunately, neither is available.

The method adopted in this analysis, is to use aggregate data on new planting, replanting en uprooting (cf. table 8.2), and to derive mathematically formulated discarding systems, which accurately relate discarding of area to new planting and replanting in the past, resulting in a distribution of the area by age. Underlying this analysis is the argument that if one would know in year t what the area per vintage τ is, say $a_{t\tau}$, and if one would also know which percentage according to a theoretical discarding system would be discarded for each vintage τ depending on the age of the vintage, $t-\tau$, then one could calculate the area per vintage as well as the total discarded area. However, the parameters of the discarding system are not known. Now turning around the argument: given data on a distribution by vintages in a year, total discarding of area in the following year may act as a criterion to select among theoretical mathematically formulated discarding systems. Afterwards, discards of trees can be allocated to vintages, using the selected discarding system, and the distribution by vintages can be developed year by year. Thus, for each year, theoretical discarding by vintage is adjusted to take care of e.g. diseases or high levels of replanting; this is the basis for discarding for the following year.

The above analysis requires a vintage distribution in the starting year, say 1955. Using data on planting in the years up to 1955 as well as a number of feasible mathematically formulated discarding systems, one may derive a number of feasible vintage distributions in the starting year. That discarding system and the corresponding starting year vintage distribution may now be selected, which provides an optimal fit to data on discarding for the sample period, from the starting year onwards (cf. figure 8.1 for an example).

Table 8.2 *Rubber area of smallholdings, Peninsular Malaysia (1,000 hectares)*

	(1)	*(2)*	*(3)*	*(4)*	*(5)*	*(6)*	*(7)*
	planted area, end of year	*new planting*	*re-planting*	*new trees*	*other increase*	*addition e.g. from estates*	*loss e.g. to other crops*
			(b)	*(2)+(3)*	*Δ(1)-(2)*		*(6)-(5)*
1955	722.1	3.2	10.1	13.3		5.3	
1956	735.5	5.7	18.6	24.3	7.7	8.9	1.2
1957	746.4	6.9	19.8	26.7	4.0	5.3	1.3
1958	775.6	12.6	23.1	35.7	16.6	17.8	1.2
1959	813.2	17.8	27.9	45.7	19.8	21.1	1.3
1960	850.1	26.7	27.9	54.6	10.2	10.9	0.7
1961	891.8	38.9	23.1	62.0	2.8	3.6	0.8
1962	940.4	44.1	27.9	72.0	4.5	5.3	0.8
1963	978.1	34.7	33.6	68.0	3.3	4.9	1.6
1964	1,007.2	24.7	32.0	56.7	4.4	7.3	2.9
1965	1,022.6	13.4	36.9	50.3	2.0	6.1	4.1
1966	1,041.3	10.9	19.8	30.7	7.8	9.3	1.5
1967	1,054.6	7.7	30.4	38.1	5.6	11.7	6.1
1968	1,059.1	5.7	15.8	21.5	-1.2	3.2	4.4
1969	1,067.1	6.3	15.1	21.4	1.7	1.7	0
1970	1,077.3	11.0	21.5	32.5	-0.8	0	0.8
1971	1,086.5	12.4 a)	23.3	35.7	-3.2	0	3.2
1972	1.092.0	9.5 a)	23.4	32.9	-4.0	0	4.0
1973	1,104.6	12.6 a)	28.6	41.2	0	0	0
1974	1,117.6	5.5	23.6	29.1	7.5	7.5	0
1975	1,131.6	10.9	21.1	32.0	3.1	3.1	0
1976	1,147.8	9.5	14.3	23.8	6.7	6.7	0
1977	1,163.9	9.9	12.9	22.8	6.2	6.2	0
1978	1,175.7	20.6	13.3	33.9	-8.8	0	8.8
1979 p)	1,194.0	18.0	15.0	33.0	0.3	0.3	0
1980 p)	1,209.0	6.0	15.0	21.0	0	0	0

p) = provisional
a) refers to FELDA-scheme only
b) refers to those smallholdings receiving assistance from RISDA only

Sources: Rubber Statistics Handbook and Thomas (1970) (cf. table 8.8)

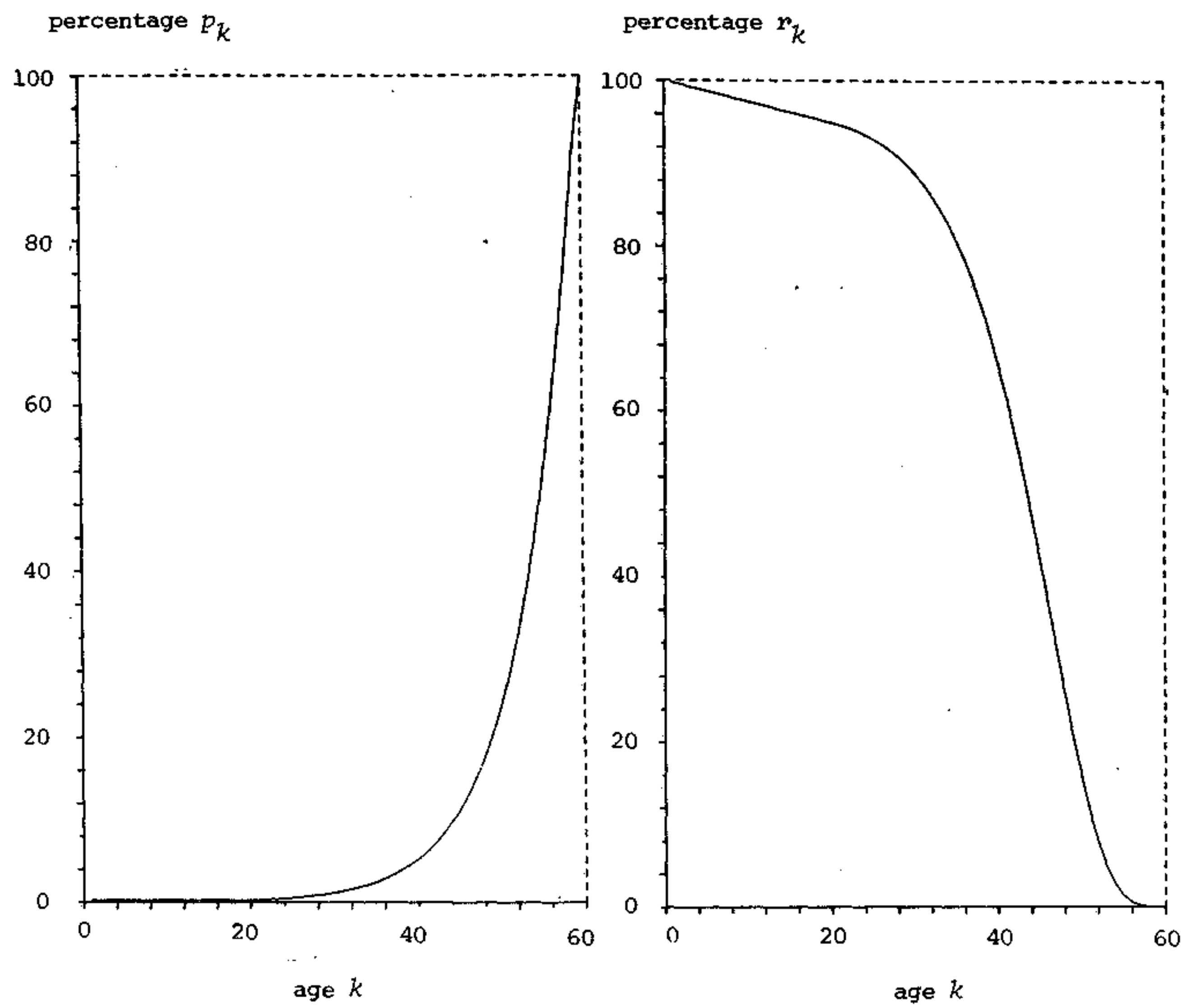


Figure 8.1 *Percentage of remaining area, discarded in year k (p_k) and percentage of original area remaining after k years (r_k) with a constant reduction in r_k to 95 % after 20 years.*

b. *Yield profiles*

As has been elaborated upon in chapter 7, trees of different age on average have a different yield. Yield profiles for some of the popular clones have been indicated. It is clear that in this study no detailed analysis of the area for the various clones can be undertaken. Because of the large degree of aggregation that is inevitable in the set-up of this study, an average of the various yield profiles has been used (cf. table 7.3). Clones used in this average yield profile are RRIM 600, PR 225, PR 261, RRIM 527, AVROS 2037, GT 1 and PB 28/59. The resulting average yield profile functions as an ideal yield profile and is presented in table 8.3. From the 31st year of tapping onwards, the yield profiles have been derived by straightforward extrapolation in order to complete the picture for very old trees. Tapping methods cause the yield profile to have a 5-year's cycle. These yields are obtained under experimental conditions. In commercial practice, yields will be somewhat lower, although the shape of the yield profile may still be valid. The high yields between 10 and 20 years after tapping must partly be contributed to stimulation. Therefore, for smallholders, an alternative yield profile has been used, with a maximum of 1,900 lbs per acre or 2,130 kgs per hectare.

Above, it has been indicated that the actual (commercial) yield profile will be lower than the ideal yield profile. The ideal yield profile therefore needs to be multiplied with a certain factor, in order to reduce the ideal yield profile to actual levels. This multiplication factor will be different for different countries, and, within countries, for estates and smallholdings. A reason may be the selection of clones. This selection of clones of which a certain vintage is composed may vary over time, implying that the multiplication factor may need to increase over time in view of technical progress. The assumption now is that each vintage will have an average yield profile, which is a constant fraction of the ideal yield profile: if a yield profile is estimated to be for example 0.3 times the ideal yield profile, then the profile is suppressed to 30 percent of the original shape with a value of 330 kgs per ha in the second year of tapping. Of course, later vintages may be composed of better clones, thus increasing average yield. In the example, the fraction of 0.3 may become 0.4 after a number of years. The fractions are estimated per vintage in the following paragraphs, by relating area and ideal yield profile to production and then deriving the fractions which create actual yield profiles that are consistent with area composition and production. In figure 8.3, for example estimated yield profiles for estates for the 1950 and the 1980 high-yielding vintages are presented which are about 60 percent and 90 percent respectively of the ideal yield profile. As a matter of clarification, this means that trees planted in 1950 have a yield profile which is about 60 percent of the ideal yield profile. This vintage of course will only reach high production levels after 1966. These shifts will be dealt with below in part c: technical progress.

Table 8.3 *Ideal yield profile (kgs per ha)*

Year of tapping	*Yield*	*Year of tapping*	*Yield*
1	816	27	1,601
2	1,100	28	1,431
3	1,467	29	1,200
4	1,717	30	1,200
5	1,849	31	1,166
6	1,884	32	1,098
7	2,167	33	1,009
8	2,033	34	919
9	2,084	35	841
10	2,033	36	762
11	3,149	37	672
12	3,267	38	616
13	2,984	39	549
14	2,400	40	482
15	2,167	41	426
16	2,783	42	381
17	2,416	43	336
18	2,334	44	280
19	2,007	45	224
20	1,830	46	191
21	2,350	47	157
22	1,900	48	112
23	1,766	49	90
24	1,650	50	56
25	1,434	51	22
26	1,431	52	11

Source: based on table 7.3 (see text).

c. *Technical progress and production capacity*

There are a number of factors which have contributed to the increase in productivity of rubber land. By far the most important one is the improvement of the quality of trees. This partly needs to be combined with the application of fertilizers and possibly stimulants. All this may be put under the collective name "embodied technical progress". There is another group of factors improving yield of rubber land which may be called "disembodied technical progress". To this group belong such aspects as improved tapping methods. Embodied technical progress, embodied in the quality of the trees and thus in the vintages is by far the most important group. It has therefore been decided to emphasize the inclusion of embodied technical progress in the analysis, which then can be specified as a function of the vintage, the year of planting.

The specification of the production function must be such that
- area distribution by vintage
- yield profiles
- technical progress

are the three elements of a function explaining production capacity. In order to be able to estimate parameters of a technical progress function one must determine production capacity. Determination of the level of production capacity in each year, however, causes a lot of problems. Therefore, production, being the degree of capacity utilization times production capacity has been used instead.

What influences the degree of capacity utilization? It may be expected that almost all of it may be explained from development of the price of NR indicated with P. However, it is not a priori clear in which way P influences the degree of capacity utilization. A few possibilities are considered:

(i) P has a positive influence on capacity utilization, which is a classical approach along the lines of a supply curve.

(ii) Changes in P rather than levels of P influence behaviour of rubber smallholders, which then again may be split into increasing prices and decreasing prices as reactions may be different in these two cases.

(iii) P only affects production if P is very low: there will be partly a switch to other modes of earning a living.

(iv) Finally it might even be assumed that very high levels of P tend to reduce production because adequate income can be obtained with lower levels of production.

(v) It may be appropriate to deflate all prices for the above possibilities; a general price deflator may be used.

Next to NR prices, other variables may occasionally influence the degree of capacity utilization. A phenomenon which has gained momentum recently is insufficient availability of manpower to utilize existing production capacity. In the optimal estimation result, the possibilities (ii), (iii) and (iv) together with the availability of labour factor and a linear embodied technical progress function could be successfully included. The fit was very good. Actual and estimated production figures are graphically represented in figure 8.2.

An illustration of the resulting relationship between ideal yield profile, actual yield profile and the embodied technical progress function will be given for the case of estates. Projections of production for various policies in new planting and replanting will be presented in section 8.6.

Peninsular Malaysia, estates model

Production of estates has almost doubled over the past 25 years, as can be seen in table 8.1. A major cause of this development is the change in composition of the rubber area of estates towards higher yielding trees. As in the case of smallholdings it is therefore very important to include the year of planting in the analysis, thus pursuing a vintage approach. The analysis broadly runs parallel to the smallholdings' analysis, including the following aspects:

a. area distribution by vintages
b. yield profiles, technical progress and production.

At the end projections of NR production for various systems of new planting and replanting can be derived and assessed.

a. *Area distribution by vintages*

Data on area under rubber

Data on rubber area of estates have been compiled from the same two sources: the Rubber Statistics Handbook of Malaysia (several issues) and Thomas (1970). They are presented below in table 8.4. For the analysis it is useful to distinguish between three types of trees

- unselected seedlings
- pre-war high-yielding
- post-war high-yielding,

because of differences in age, yield and technical developments.

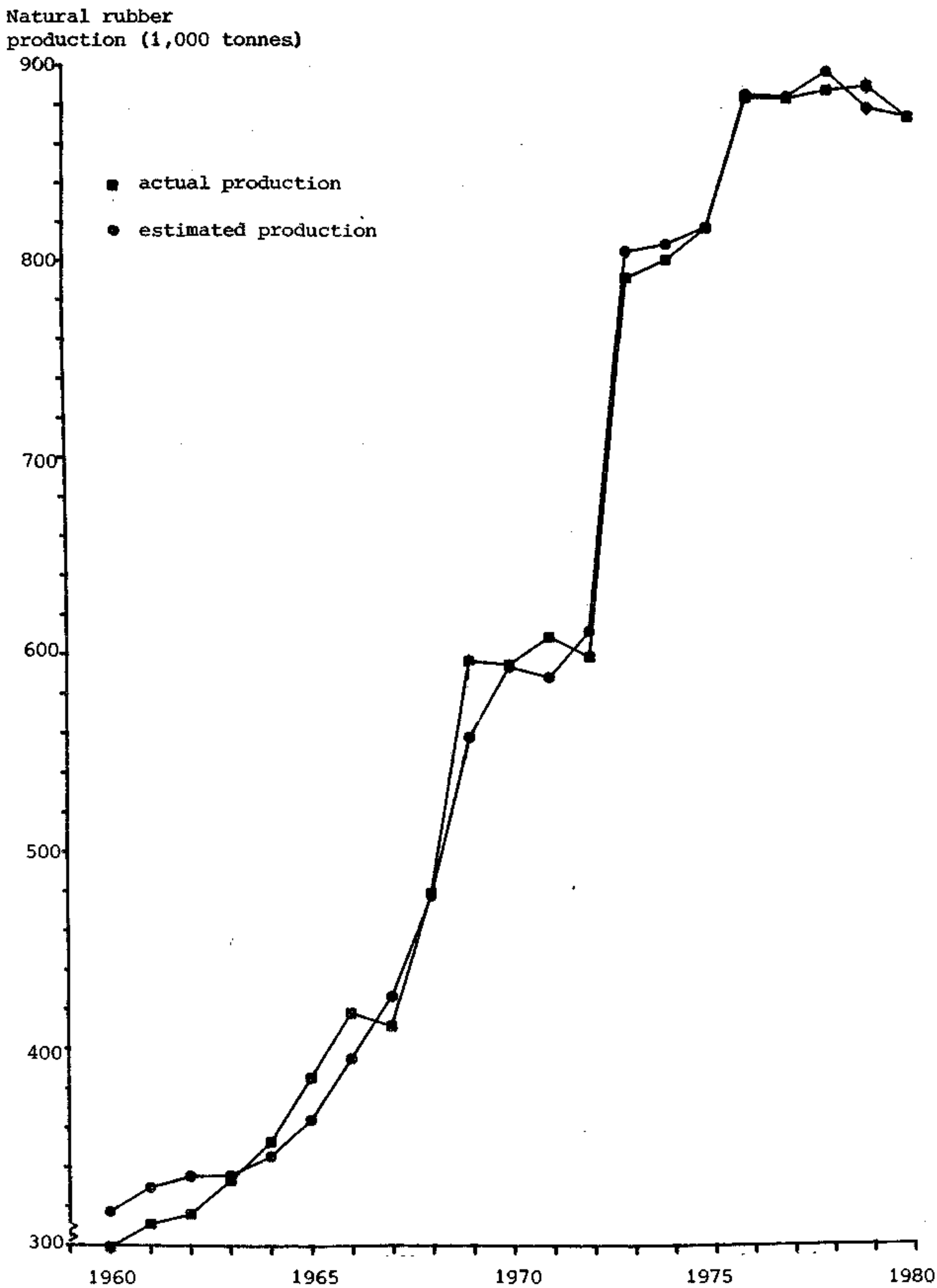


Figure 8.2 *Actual and estimated natural rubber production (in 1,000 tonnes), equation (8.21a)*

Table 8.4 *Rubber area estates, Peninsular Malaysia (1,000 hectares)*

	(1) Planted high-yielding	(2) Planted unselected seedlings	(3) Planted total	(4) New planting high-yielding	(5) New planting unselected seedlings	(6) New planting total	(7) Replanting with high-yielding	(8) Replanting with unselected seedlings	(9) Replanting total	(10) New trees total
	(11)+(17)	(12)+(18)	(1)+(2)			(4)+(5)			(7)+(8)	(6)+(9)
1955	325.5	490.3	815.8	3.6	0.4	4.0	25.3	2.7	28.0	32.0
1956	357.4	455.5	812.9	5.5	0.5	6.0	35.0	3.0	38.0	44.0
1957	391.8	422.7	814.5	5.6	0.4	6.0	34.4	2.6	37.0	43.0
1958	420.0	382.7	802.7	5.6	0.4	6.0	29.9	2.1	32.0	38.0
1959	435.8	350.3	786.1	5.7	0.3	6.0	31.2	1.8	33.0	39.0
1960	466.3	316.7	783.0	8.5	0.5	9.0	37.0	2.0	39.0	48.0
1961	501.0	283.7	784.7	6.7	0.3	7.0	34.2	1.8	36.0	43.0
1962	528.2	252.0	780.2	3.9	0.2	4.1	24.4	1.1	25.5	29.6
1963	554.2	223.0	776.4	3.4	0.1	3.5	23.3	0.5	23.8	27.3
1964	573.9	192.8	766.7	2.5	0.0	2.5	23.6	0.3	23.9	26.4
1965	586.8	166.1	752.9	2.0	0.0	2.0	21.0	0.5	21.5	23.5
1966	597.7	136.7	734.4	1.2	0.1	1.3	19.5	0.8	20.3	21.6
1967	599.7	108.1	707.3	1.0	0.0	1.0	10.9	0.4	11.3	12.3
1968	592.3	85.9	678.2	0.2	0.0	0.2	5.2	0.1	5.3	5.5
1969	587.2	76.0	663.2	0.9	0.9	0.9	9.3	0.4	9.7	10.6
1970	581.1	65.4	646.6	1.2	0.0	1.2	13.7	0.4	14.1	15.3
1971	579.1	52.5	631.6	2.4	0.0	2.4	11.9	0.2	12.1	14.5
1972	568.7	41.6	610.3	2.2	0.0	2.2	7.9	0.1	8.0	10.2
1973	558.0	31.4	589.4	2.3	0.0	2.3	9.6	0.1	9.7	12.0
1974	548.2	26.0	574.2	1.9	0.0	1.9	12.1	0.1	12.2	14.1
1975	545.9	17.4	563.3	2.6	0.0	2.6	11.1	0.1	11.2	13.8
1976	540.4	12.9	553.3	1.2	0.0	1.2	8.4	0.1	8.5	9.7
1977	528.1	10.8	538.9	2.1	0.0	2.1	7.3	0.1	7.4	9.5
1978	514.8	8.4	523.2	0.6	0.0	0.6	7.2	0.0	7.2	7.8
1979p	502.4	7.5	509.9	0.5	0.0	0.5	7.0	0.0	7.0	7.5
1980p	493.6	6.4	500.0	0.5	0.0	0.5	7.0	0.0	7.0	7.5

Table 8.4 (continued)

	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)	(21)	(22)	(23)	(24)	(25)
	Immature high-yielding	*Immature unselected seedlings*	*Immature total*	*Maturing unselected seedlings*	*Mature pre-war high-yielding*	*Mature post-war high-yielding*	*Mature high-yielding*	*Mature unselected seedlings*	*Mature total*	*Transfer to other crops and smallholdings*	*Discarded trees*	*Discarded pre-war high-yielding*	*Discarded unselected seedlings*	*New trees high-yielding*	*Post-war high-yielding*
			(11)+(12)	(5)+(8)-Δ(12)			(15)+(16)		(17)+(18)	(6)-Δ(3)	(9)+(20)	-Δ(15)	-Δ(18)+(5)+(8)-(t-7)	(4)+(7)	(1)-(15)
1955	110.0	27.0	137.0		171.4	44.1	215.5	463.3	678.8					28.9	154.1
1956	127.0	25.0	152.0	5.5	162.8	66.8	230.4	430.5	661.0	8.9	46.9	8.6	34.0	40.5	194.6
1957	146.0	23.0	169.0	5.2	157.2	87.5	245.8	399.7	645.6	4.4	41.4	5.6	34.0	40.0	234.6
1958	160.0	21.0	181.0	4.5	149.9	107.7	260.0	361.7	621.7	17.8	49.8	7.3	43.0	35.5	270.1
1959	175.0	19.0	194.0	4.1	128.8	127.1	260.8	331.3	592.1	22.6	55.6	21.1	36.0	36.9	307.0
1960	197.0	17.0	214.0	4.5	113.8	146.2	269.3	299.7	569.0	12.1	51.1	15.0	36.0	45.5	352.5
1961	211.0	16.0	227.0	3.1	107.6	169.7	290.0	267.7	557.7	5.3	41.3	6.2	36.0	40.9	393.4
1962	212.3	15.1	227.4	2.1	106.5	198.5	315.9	236.8	552.7	7.9	33.4	1.1	34.0	28.3	421.7
1963	211.8	12.0	223.8	3.5	105.8	230.0	342.3	211.2	553.5	7.3	31.1	0.7	29.0	26.7	448.4
1964	206.7	11.2	217.9	1.1	99.4	262.0	367.2	181.6	548.8	12.2	36.1	6.4	33.0	26.1	474.5
1965	197.6	10.5	208.0	1.2	89.3	295.2	389.2	155.6	544.8	15.8	37.3	10.1	28.0	23.0	497.5
1966	182.6	8.1	190.7	3.3	79.5	334.5	415.1	128.6	543.8	19.8	40.1	9.8	29.0	20.7	518.2
1967	158.4	3.7	162.0	4.8	69.6	375.8	440.9	104.4	545.3	28.1	39.4	9.9	27.0	11.9	530.1
1968	131.0	1.6	132.6	1.8	60.0	410.3	461.4	84.3	545.7	29.3	34.8	9.6	22.0	5.4	532.3
1969	109.0	2.5	111.5	0.3	52.0	439.8	478.2	73.5	551.7	15.9	25.6	8.0	12.0	10.2	535.2
1970	97.9	4.0	101.9	0.0	44.0	439.3	483.3	61.4	544.7	17.8	31.9	8.0	13.0	14.9	537.1
1971	94.0	3.8	97.8	0.3	37.0	448.1	485.1	48.7	533.9	17.4	28.5	7.0	13.0	14.3	542.1
1972	86.9	1.3	88.2	0.8	32.0	449.9	481.9	40.2	522.1	23.5	31.5	5.0	9.0	10.1	536.7
1973	78.2	3.3	81.5	0.0	27.0	452.8	479.8	28.2	508.0	23.2	23.9	5.0	13.0	11.9	531.0
1974	81.7	2.4	84.1	0.4	22.0	444.4	466.4	23.6	490.1	17.3	29.5	5.0	5.0	14.0	526.2
1975	89.7	1.2	90.9	1.3	17.0	439.3	456.3	16.2	472.4	13.5	24.7	5.0	7.0	13.7	528.9
1976	90.4	0.7	91.1	0.6	13.0	437.0	450.0	12.2	462.2	11.2	19.7	4.0	5.0	9.6	527.4
1977	86.2	0.7	87.0	0.1	8.8	433.1	441.9	10.0	451.9	16.5	23.9	4.2	2.0	9.4	519.3
1978	80.1	0.6	80.8	0.1	6.0	428.7	434.7	7.7	442.4	16.3	23.5	2.8	1.0	7.8	508.8
1979P	77.0	0.5	77.5	0.1	3.0	422.4	425.4	7.0	432.4	13.8	20.8	3.0	1.0	7.5	499.4
1980P	75.0	0.4	75.4	0.1	1.0	417.6	418.6	6.0	424.6	10.4	17.4	2.0	1.0	7.5	492.6

p = provisional

Sources: Rubber Statistics Handbook (RSH) for 1962-1978 col. (3), (6), (9), (11), (12), (13), (17), (18).
Thomas (1970) for 1955-1961 col. (3), (6), (9), (13), (17), (18).
Division of (17) into (15) and (16) based on Thomas (1970) and RSH using scattered information: Δ(25) = (24), (15) = (1) - (25) and (16) = (17) - (15) up to 1967; (25) = (1) - (15), (16) = (17) - (15) from 1968 onwards. Col. (11) and (12) before 1962 are derived similarly.
Division of (6) into (4) and (5) as well as (9) into (7) and (8) are based on composition of (11) and (12) in (13) at year $t+4$.

b. *Yield profiles, technical progress and production*

Yield profiles

For estates the same ideal yield profile has been selected as presented in table 8.3. The technical progress functions for each type of rubber area again act as a correction factor, proportionately moving the yield profile downwards.

Technical progress and production

As in the case of smallholdings attention will only be paid to embodied technical progress. Production capacity was, as a first step, derived from a line through the tops of the graphs of actual production. However, it seemed that production and production capacity were too close to be distinguished. It therefore seems that production is always at capacity levels. Prices will then have very little or no effect on production. There is an optimal long run tapping system which is followed by estates that have good husbandry.

In view of the disaggregation of area, even more specifications could be tested than in the case of smallholders. Optimal estimation results for the sample period 1960-1980 have been obtained. Some output depressing influence of labour-shortage has been estimated using an exponential function as correction factor from 1974 onwards. It has not been possible as expected to include any effect of price levels or price changes.

The embodied technical progress functions provide reduction factors for the ideal yield profile. Then the yield profiles for the vintages can be calculated. Figure 8.3 shows the yield profiles for the vintages:

unselected seedlings	1929:	reduction factor = 0.4145
pre-war high-yielding	1929:	reduction factor = 0.5334
post-war high-yielding	1980:	reduction factor = 0.7845.

East-Malaysia: the model

Availability of data on the rubber industry in Sabah and Sarawak is very limited. Data on area are available since the early 1970's. They do not show an upward or downward trend, though there are some shifts between smallholders area and estate area. Total area in Sabah was about 105,000 ha throughout the 1970's while total area in Sarawak remained rather constant at 190,000 ha.

Detailed information on rubber production is shown in table 8.5. Production could be related to last year's production, price changes and linear trends for Sabah and Sarawak separately. More refined methods could not be applied.

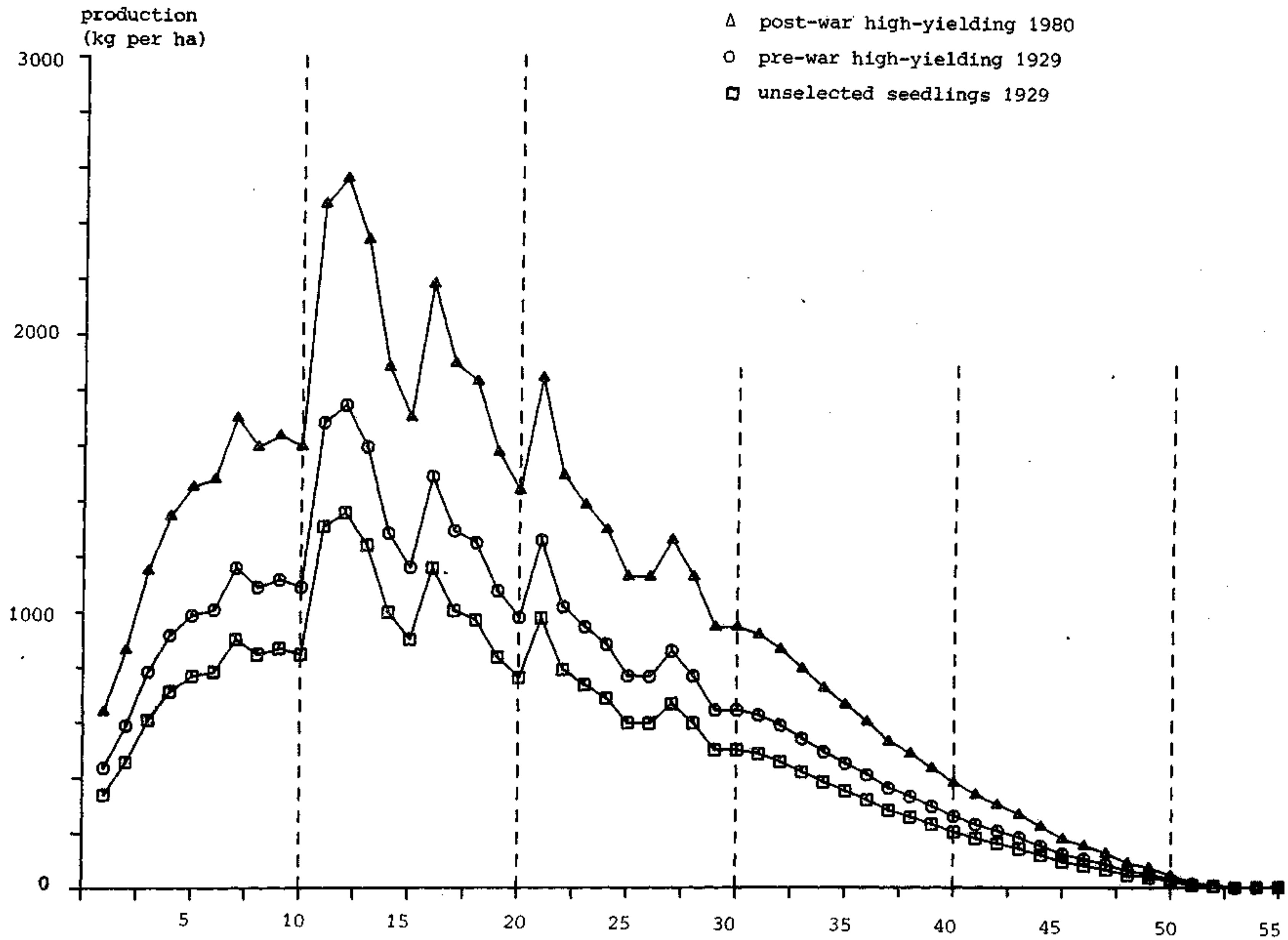


Figure 8.3 *Estimated yield profiles for three vintages of estates (see text)*

Table 8.5 *Natural rubber production in Sabah and Sarawak (in 1,000 tonnes)*

	Sabah	*Sarawak*	*Total*
1961	24.0	44.3	68.3
1962	22.7	34.2	56.9
1963	21.6	44.3	65.8
1964	23.2	43.6	66.8
1965	24.2	40.7	64.9
1966	24.1	34.0	58.1
1967	24.1	28.2	52.3
1968	24.9	24.1	49.0
1969	29.4	39.2	68.6
1970	31.8	21.7	53.5
1971	28.6	19.5	48.1
1972	26.3	19.9	46.2
1973	35.3	41.8	77.2
1974	31.6	32.6	64.2
1975	32.0	29.0	61.0
1976	35.8	40.3	76.1
1977	38.8	37.6	76.4
1978	36.8	39.6	76.4
1979	33.2	38.6	71.8
1980	30.8	35.2	66.0

Source: Rubber Statistical Bulletin

8.2 INDONESIA

General aspects

Rubber production has reached a low in 1963 and has peaked in 1969, reaching this peak value again in 1973. It was only in 1978 to 1980 that production was higher than in 1973. A very high growth was achieved in 1980, bringing total production just above 1 million tonnes. Al this may be an indication of a strong influence of price developments on production. For more information, see table 8.6.

Table 8.6 *Production of NR in Indonesia (1,000 tonnes)*

	estates	*smallholdings*	*total*
1955	266.3	482.6	748.9
1956	265.8	431.8	697.6
1957	257.4	438.0	695.4
1958	244.9	451.3	696.2
1959	224.0	480.6	704.6
1960	215.6	404.6	620.2
1961	223.2	459.0	682.2
1962	209.3	472.0	681.3
1963	208.3	373.6	581.9
1964	223.2	425.2	648.4
1965	219.7	496.9	716.6
1966	208.8	527.9	736.7
1967	200.5	500.3	700.8
1968	233.5	560.4	793.9
1969	230.8	649.6	880.5
1970	236.8	578.4	815.2
1971	238.7	580.6	819.3
1972	214.0	559.6	773.6
1973	223.1	662.7	885.8
1974	248.4	606.6	855.0
1975	244.1	577.5	822.5
1976	246.8	600.0	847.5
1977	252.2	582.8	835.0
1978	269.4	633.1	902.5
1979	273.6	631.4	905.0
1980	281.0	739.0	1,020.0
1981	290.1	577.4	867.5

Source: Rubber Statistical Bulletin.

Production of estates decreased in the fifties, remained low in the sixties and has increased again in the seventies. Total rubber area, however, has slightly decreased. When the various estates are divided according to type of ownership, large differences can be observed. Public estates are proceeding very well contrary to what is usually assumed about public enterprise. Private national estates are doing poorly owing to such factors as low quality management. Private foreign estates are in between. All types of estates show a slight decrease in acreage over the past decade (see table 8.7).

For smallholders slightly different remarks can be made. Production has been highly unstable in the fifties and sixties but did not show a significant trend. However, in the late sixties and the seventies, output has increased rapidly from about 500,000 tonnes in 1965 to peak levels of 650,000 tonnes in 1969, 660,000 tonnes in 1973 and 750,000 tonnes in 1980, in spite of a slow increase in area only (see table 8.7). Apart from price induced increase in the short-run, some effects on the trend level may have been obtained through better quality of trees. However, annual yield per hectare is still in the order of 300-400 kg only. Average yield of estates is not much higher, although there are vast differences between the three types of estates.

There are many reasons for this lagging behind of Indonesian rubber production compared with Malaysia. An elaborate survey has recently been given in a paper coordinated by the Department of Trade and Cooperatives (1980). Many reasons, some of which apply to smallholdings only, have been reviewed in that paper.

Table 8.7 *Natural rubber area in Indonesia (1,000 hectares)*

	Public estates	*Private estates*	*Smallholdings*	*Total*
1964	206.2	301.3	1,598.6	2,106.2
1965	212.6	313.5	1,608.7	2,134.9
1966	249.2	289.4	1,626.3	2,164.9
1967	222.8	291.9	1,617.0	2,131.7
1968	228.3	290.7	1,689.7	2,208.7
1969	221.5	294.1	1,771.4	2,286.9
1970	223.6	280.6	1,813.1	2,317.3
1971	221.4	306.9	1,811.3	2,339.6
1972	197.4	305.9	1,840.5	2,343.8
1973	216.3	275.1	1,856.6	2,347.9
1974	197.2	259.1	1,872.8	2,329.1
1975	201.8	254.7	1,864.2	2,320.7
1976	197.0	251.6	1,857.1	2,305.7
1977	189.7	236.4	1,864.9	2,291.0
1978	188.5	253.3	1,870.6	2,312.4

Source: Directorat General of Plantations (1980)

Indonesia, the estates model

The approach to modeling estates' natural rubber production in Indonesia is similar to the Malaysian case. The sample period is 1964-1980. It has again been attempted to include the year of planting in the analysis in order to cover the following influences:

- the quality of the vintage may increase for newer vintages
- trees become less productive after reaching a certain age
- immature trees are not yet productive.

It is for these reasons that a vintage approach has been applied. An elaborate description of the model has been presented for Malaysian smallholdings.

It has already been stated that productivity is different for public estates and for private estates. For this reason the analysis has been done with possibility of different parameters for the two types of estates.

a. *Area distribution public estates*

Total area for private estates and for public estates as well as for smallholdings is available from 1964 onwards, table 8.7. Using these data as well as information on the area distribution in 1977 by year of planting (table 8.8), a discarding system has been selected and rubber area by vintage has been derived.

Table 8.7 shows changes in area from year to year which can not be attributed to new planting or uprooting. These inaccuracies in the data will of course also be reflected in the vintage distribution. It may then occur that a vintage increases in size in a certain year without any reasonable explanation. The effects of such a development will again be taken up under c: the relationship between production and area by vintage.

b. *Area distribution private estates*

From the 1973 agricultural census, data on the area distribution by year of planting of all rubber estates are known: table 8.9. On the basis of the estimated area distribution for public estates in 1973 and total private estates area (table 8.7), the area distribution by vintage could be derived. Discarding percentages for private estates are much lower than for public estates, leading to relatively high ages of trees and low aggregate yield levels on private estates. Similar remarks as for public estates apply for unexplainable variation in vintage size from year to year.

c. *Estate natural rubber production*

The analysis relating natural production to vintages in Indonesia is similar to the approach for Malaysia. Because of the unsuccessful experience with the analysis of production capacity for Malaysia, here only production is explained. Disembodied technical progress could not successfully be included, as was also the case for Malaysia.

Table 8.8 *Public estates: area planted to rubber in 1977 (in 1,000 hectares)*

Year of planting	*Area*	*Year of planting*	*Area*
pre-1951	12.25	1964	10.28
1951	1.75	1965	10.85
1952	2.60	1966	12.43
1953	2.55	1967	12.80
1954	4.01	1968	11.03
1955	4.12	1969	9.49
1956	4.66	1970	8.12
1957	5.56	1971	6.19
1958	5.73	1972	4.58
1959	4.62	1973	6.21
1960	5.92	1974	8.71
1961	7.59	1975	7.06
1962	7.91	1976	3.81
1963	8.88	1977	4.20

Source: Directorat General of Plantations (1980)

Table 8.9 *All estates, area planted to rubber in 1973 (in 1,000 hectares)*

Year of planting	*Area*	*Year of planting*	*Area*
1940/41 or before	161.86	1967/68	24.24
1941/42-1945/46	12.00	1968/69	18.88
1946/47-1950/51	8.78	1969/70	20.36
1951/52-1955/56	32.34	1970/71	23.53
1956/57-1960/61	62.27	1971/72	15.09
1961/62-1965/66	85.57	1972/73	19.20
1966/67	21.89		

Source: Agricultural Census 1973

For the years 1969-1978 for which production could be split into its composing parts for public estates and private estates, the separate data and not the aggregate has been used as dependent variable. The final estimation result includes linear embodied technical progress functions, being different for public estates and private estates. Besides, price changes could be included.

Above it has been indicated that total area for each of the two types of estates is fluctuating more than is compatible with data on uprooting and new planting. These inaccuracies in the area data are reflected in the vintages as well and may therefore disturb the relationship between production and vintages. If production develops according to a trend, a normal development in area, and if it is explained by inaccurate area data, it may be good to include as correction factor the trend value of the area divided by the actual area. This correction factor has been derived as the inverse of the ratio of the aggregate area data for estates and their three years moving average. The estimated exponent of this ratio turns out to be close to unity, which justifies its use and the assessment that there are inaccuracies in data on area.

Indonesia, the smallholdings model

It has been attempted to apply the same approach as for Indonesian estates, thus including estimated years of planting in the analysis. The vintage approach has been presented in detail for Malaysian smallholdings.

a. *Area distribution*

Total planted area for smallholdings is given in table 8.7. However, no information is available from a census such as in the case of estates. For want of better evidence it has been assumed, that the area composition of the area in 1973 was similar to the area distribution of private estates, which has also strongly been lagging behind.

b. *Smallholdings natural rubber production*

From the estimation results as well as from table 8.6, it can be concluded that the years 1964-1967, years of political changes, show a lower level for smallholdings than would be expected in view of production in subsequent years. These years are therefore excluded from the analysis. Using a linear technical progress function and for the period 1968-1980 price influence specified as price ratios and some adjustments for the 1973 figure gives optimal results.

8.3 THAILAND

General aspects

Rubber area is almost completely located in the South of Thailand, in the peninsula. A very small part is found in the North-East of Thailand. Only a few percent of Thai NR production is in the hands of estates.

NR production has gone up strongly over the past decades with a major increase in the seventies (cf. table 8.10). Doubling of production occurred between 1968 and 1979. This has been possible because of major new planting and replanting. New planting reached levels of over 30,000 ha on average annually in the decade after the Second World War, and, again, gained momentum in the first half of the sixties (over 60,000 ha on average annually) with a level declining to some 25,000 ha per year currently.

Table 8.10 *Production of NR in Thailand (1,000 tonnes)*

Year	*Production*	*Year*	*Production*
1960	170.9	1971	318.8
1961	186.1	1972	336.9
1962	195.4	1973	390.0
1963	189.8	1974	379.5
1964	221.6	1975	355.0
1965	216.4	1976	411.9
1966	207.5	1977	430.9
1967	216.1	1978	467.0
1968	259.2	1979	531.2
1969	283.4	1980	501.1
1970	289.7	1981	504.0

Source: Rubber Statistical Bulletin

Replanting of old trees largely with high-yielding clones started after the introduction by the government of the Rubber Replanting Aid Fund in 1961. A World Bank project strongly contributed to the success of the replanting program with peaks of over 100,000 ha per year in 1972 and 1973. Tappable area in 1979 was about 1,170,000 ha. It has recently been expressed at the 27th Assembly of the International Rubber Study Group in June 1982, that future growth of NR production in Thailand might be depressed because of prevailing low prices and that production might reach 600,000 and 1,000,000 tonnes respectively in 1985 and 1990.

The model

In view of the importance of Thailand's contribution to world rubber production, a vintage model has been used along the lines of the model for Malaysian smallholdings.

a. *Area distribution*

In a recent paper prepared in the context of a study on maximum production potential for Thailand, data are presented on new planting and replanting in Thailand, as well as on total area under rubber. They are presented here in table 8.11. Clearly, the data base underlying table 8.11 is not very strong. A very reliable part is presumably the series on replanting where applications, approvals and executions are used, as registered by the Rubber Replanting Aid Fund Office in Bangkok.

In the bulletin "Thailand Rubber Statistics" by the Department of Agriculture, the results are reported of two surveys: A survey of Rubber Growing Area (Technical report 1) with data for 1966; and Area of Rubber in Thailand from Satellite Survey (Rubber Research Centre, Hat Yai) with data for 1978. These data show a large discrepancy with the data in table 8.11: area in 1966 is estimated at 1,262,690 ha and in 1978 at 1,476,280 ha. Using these figures as a basis, the yearly increase has been reduced according to the pattern of table 8.11. Obviously a similar reduction had to be used for data on new planting.

For Thailand, no data are available on area distribution by year group, which then could function as the basis for the construction of the vintages. Therefore data on new planting in the past had to be used, which, then, by applying the selected discarding system could be transformed into vintages remaining in the years 1966-1980, the sample period for the analysis of production.

Data on new planting have been constructed by several authors (cf. Rubber Research Centre, Thailand (1976)). The basis for ex-post calculation of the data is als follows. Using production data since the beginning of the century, a correction is applied using an estimated price elasticity. In this way an estimated series of production capacity is obtained. The necessary increase in area is calculated by dividing production (increase) by an estimate of production per hectare which is constant throughout the period.

Table 8.11 *Rubber area in Thailand (in 1,000 ha)*

Year	*Total area*	*New planting*	*Replanting*
1966	1,181.82	38.50	3.80
1967	1,216.95	35.16	5.92
1968	1,262.62	33.33	10.66
1969	1,295.78	33.33	12.00
1970	1,329.12	33.33	12.88
1971	1,362.45	33.33	18.83
1972	1,395.78	33.33	24.48
1973	1,429.11	33.33	26.45
1974	1,462.45	33.33	20.75
1975	1,495.78	33.33	22.85
1976	1,520.85	25.00	25.08
1977	1,545.85	25.00	37.52
1978	1,570.85	25.00	45.78

Source: The current national policies and development in Thailand, paper prepared for a study on maximum production potential for the Association of Natural Rubber Producing Countries.

Of course the approach has many weak points, but it may act as a reasonable way of getting an approximation for area data. There is, however, one aspect which is in contradiction to our analysis: the absence of a trend in the production per hectare, whereas in our study technical progress is presupposed. In order to include this aspect, a linear correction trend has been used in order to increase figures on new planting of many years ago, say the 1930's, more than more recent new planting figures e.g. for the 1950's.

In the above mentioned paper it is indicated that the quality of planting material has jumped to a higher level around 1970. The function embodied technical progress function has thus been broken into two parts in 1970. From the regression results it was further concluded that disembodied technical progress needed to be included in order to account for the large increase in production. On the price side, as for other models, only price ratios could usefully be included as explanatory variables.

8.4 SRI LANKA AND INDIA

Sri Lanka

Sri Lanka was the fourth largest NR producing country in 1975 with 4.5 percent of world NR production. However, it lost its fourth place to India in 1980 while its NR production declined from 152,704 tonnes in 1979 to 133,151 tonnes in 1980 or 3.5 percent of world NR production.
An important determinant for NR export from Sri Lanka has always been the rubber-rice barter with China.

Area under rubber has been rather stable, as can be concluded from data from the office of the Rubber Controller of Sri Lanka. In 1945 officially reported area was about 265,000 ha increasing to 270,000 ha in 1960. However, the agricultural census of 1962 revealed that about 42,000 ha of reported rubber land was no longer under rubber. On the one hand old rubber land has been neglected and has virtually turned into jungle. On the other hand, there is constant pressure on rubber land from urbanization and infrastructure such as roads. In 1980 there was about 210,000 ha of rubber land of which about three quarters is high-yielding. The estate sector comprises slightly less than 70 percent of total rubber area.

Replanting and new planting have been marginal in the 1970's, partly due to uncertainties regarding announced land reform programs in 1972 and 1975. In 1953 a government subsidized replanting scheme was started. It was very successful in the beginning, but response dropped dramatically in later stages. In the 1970's the average was slightly over 3,000 ha per year, that is about 1.5 percent of total area and therefore far below 3 percent required to maintain a properly composed rubber area with a maximum age of 33 years which is close to optimal. Replanting reached 5,400 ha in 1980 and is planned to reach over 11,000 ha in 1985, which would be 5.5 percent of total area, thus compensating for the lack of replanting in the past. After 1986 replanting is aimed at 8,000 ha annually. New planting is very limited e.g. replacing uneconomic coconut plantings. The level of new planting in the 1970's was in the order of 200 ha on average per year. Efforts to increase new planting in the 1980's have had some success already with 575 and 965 ha in 1979 and 1980 respectively. Plans call for a level of around 900 ha per year in the first half of the 1980's and 200 ha annually in the second half.

Production has increase from around 100,000 tonnes in the fifties and early sixties to around 150,000 tonnes in the seventies (cf. table 8.12). However, production only reached 133,000 tonnes in 1980 and dropped further to around 125,000 tonnes in 1981. At its 27th Assembly in June 1982 in Mexico City, The International Rubber Study Group agreed on projections for 1982 and 1983 of 123,000 tonnes each. Next to the low price of NR, a major reason behind this development is the decrease in tappable area from about 190,000 ha in 1979 to around 150,000 ha in 1985 if the replanting plans are realized. This means that the low level of production of about 125,000 tonnes may continue up to 1987. Afterwards there will be an increase. With some 35 percent of rubber area (to be) replanted in the 1970's and 1980's and the other 65 percent to show a further reduction in yield, one may expect an increase in average yield by the year 2000 of about 35 percent, i.e. to 800 tonnes per ha. The assumptions are that the replanted area will yield 2.5 times the yield level of the old land and the rest will lose 40 percent of the yield per ha. For projections see section 8.6.

Table 8.12 *Production of NR in Sri Lanka and India (1,000 tonnes)*

Year	*Sri Lanka*	*India*
1960	98.8	25.2
1961	97.6	27.0
1962	104.1	31.4
1963	104.8	37.2
1964	111.6	44.3
1965	118.3	49.4
1966	131.0	53.2
1967	143.2	62.3
1968	148.7	68.9
1969	150.8	80.0
1970	159.2	89.9
1971	141.4	98.9
1972	140.4	109.1
1973	154.7	123.2
1974	132.0	128.4
1975	148.8	136.0
1976	152.1	147.8
1977	146.2	151.6
1978	155.7	133.0
1979	152.7	147.2
1980	133.2	155.4
1981	123.9	150.7

India

India is one of the countries with the fastest growing NR industry (cf. table 8.12). About three quarters of total rubber area is smallholders' land. Some 80 percent of rubber land was tappable area. A feature which makes the NR producing industry operating in a different context compared to other countries, is the fact that all its NR is used by the domestic rubber-goods industry. In fact, India, is a net importer of NR.

The major cause of the growth of NR production in the sixties and seventies was new planting, averaging about 12,000 ha annually in the second half of the fifties and the early sixties. However, since then new planting decreased heavily to about 3,000 ha annually in the late seventies. On the other hand, replanting was very low, rarely reaching one percent of total rubber area.

Owing to data limitations, it has not been possible to do an elaborate analysis. It does not seem likely that the growth pattern of the past will prevail in the future. New planting will presumably be limited and replanting must be increased to about 7,000 ha per year to prevent a further lagging behind, while levels of 10,000 to 15,000 ha annually are necessary to compensate for insufficient replanting in the past. In view of this one would not expect much increase in the years to come and possibly one may expect production levels of 250,000 tonnes at the end of the 1990's as is also estimated by P.O. Thomas (1982) (cf. section 8.6).

8.5 OTHER NR PRODUCING COUNTRIES

In this section over 15 countries or groups of countries are presented, together accounting for 12 percent of world production in 1980. Data on NR production are shown in tables. Projections are presented in section 8.6, largely based on qualitative information from industry sources.

Asian countries

Data on production of NR in Burma, Philippines, Vietnam, Kampuchea, China and Other Asia are given in table 8.13.

Table 8.13 *Production of NR (1,000 tonnes) in various Asian countries*

Year	*Burma*	*Philippines*	*Vietnam*	*Kampuchea*	*China*	*Other Asia*
1960	n.a.	n.a.	76.6	37.1	n.a.	n.a.
1961	n.a.	n.a.	79.1	40.0	n.a.	n.a.
1962	n.a.	n.a.	75.2	41.6	n.a.	n.a.
1963	n.a.	n.a.	71.8	40.8	n.a.	n.a.
1964	9.0	6.0	74.4	45.8	n.a.	n.a.
1965	10.5	6.2	61.0	48.9	n.a.	n.a.
1966	9.3	6.5	48.8	51.3	n.a.	n.a.
1967	6.9	10.4	40.6	53.7	n.a.	n.a.
1968	9.8	16.4	29.7	51.3	n.a.	n.a.
1969	10.0	18.8	26.2	51.8	n.a.	n.a.
1970	9.6	20.1	28.5	12.8	n.a.	n.a.
1971	11.9	21.3	34.5	1.2	5.0	7.4
1972	13.8	22.4	20.3	15.3	10.0	7.1
1973	14.1	25.9	20.6	20.0	15.0	7.3
1974	14.9	37.2	22.0	27.5	20.0	6.5
1975	15.8	52.3	20.0	10.0	25.0	6.0
1976	16.0	58.5	32.5	20.0	35.0	5.3
1977	20.0	56.3	35.0	15.0	50.0	4.8
1978	20.0	56.6	40.0	18.0	75.0	4.8
1979	20.0	60.0	50.0	10.0	97.5	4.7
1980	20.0	65.0	50.0	n.a.	113.0	4.7
1981	20.0	65.0	40.0	1.0	128.0	n.a.

Source: Rubber Statistical Bulletin

Burma

It is very hard even to obtain an accurate figure of NR production in Burma in the past, let alone to obtain accurate information on the future. For want of different evidence a small increase will be assumed. No influence of prices has been found.

Philippines

A steep increase is one of the characteristics of Philippines' NR production although growth slowed down in the second half of the seventies. No influence of prices could be derived. This equation gives production projections up to 165,000 tonnes in the year 2000.

Vietnam and Kampuchea

Once important NR producers, Vietnam and Kampuchea have enormously suffered from war activities which have dramatically reduced NR production, virtually eliminating Kampuchea activities. Of course it is impossible to obtain reasonable forecasts. One would hope that Kampuchea would soon come back to circumstances where NR production at previous levels is feasible again.

China

China's NR production has rapidly developed, in particular on Hainan island. As no reasonable information on the future of NR production is available, one might as well add 5,000 tonnes a year as any other forecast.

Other Asia

This virtually refers to Papua New Guinea only where NR production is small and may increase over the years to come.

Projections

Guesstimates on prospective NR production in the countries of this section are given in section 8.6.

Africa

Natural rubber is produced in seven countries in Africa (table 8.14). For none of the countries has it been possible to derive projections on the basis of statistical methods. Projections are given in section 8.6.

Liberia

NR production has decreased since 1974 and there seem to be indications that a recovery is forthcoming.

Nigeria

The situation in Nigeria with respect to NR production is rather steady. Some replanting is going on. Projections are assumed to be in line with the rather constant level of the past.

Zaîre

In Zaîre, as well NR has not seen any growth. For want of different evidence NR is projected to maintain a level of 25,000 tonnes per year.

Table 8.14 *Estimated production of NR (1,000 tonnes) in African countries*

Year	*Liberia*	*Nigeria*	*Zaïre*	*Ghana*	*Cameroon*	*Centr.Afr.Rep.*	*Ivory Coast*
1960	48.4	59.5	35.6	.8	4.6	.6	.0
1961	41.2	55.7	37.7	.4	8.6	.5	.1
1962	45.4	60.1	37.5	.4	8.0	.7	.2
1963	41.3	64.2	37.6	.3	9.2	1.0	.4
1964	42.6	72.2	34.2	.3	8.9	1.0	1.6
1965	49.2	69.0	21.1	.2	11.1	.9	2.8
1966	53.0	71.0	27.5	.0	12.3	1.2	5.5
1967	62.3	47.9	30.2	.4	11.7	.8	5.8
1968	64.0	52.8	32.5	.2	8.4	1.0	7.0
1969	66.9	56.8	35.7	.2	10.7	.8	7.1
1970	83.4	65.3	40.0	.8	12.2	.5	10.9
1971	74.2	61.8	41.8	1.0	13.8	1.3	11.8
1972	83.3	57.2	43.5	1.6	12.7	1.3	12.7
1973	85.5	66.3	44.0	1.9	16.4	1.3	14.9
1974	86.2	78.0	30.8	2.5	16.3	1.3	15.2
1975	82.8	67.8	30.0	3.0	15.5	1.3	14.9
1976	82.4	52.5	29.3	3.4	18.0	1.3	17.5
1977	80.0	59.3	30.0	4.0	18.0	1.3	16.8
1978	78.5	57.5	25.8	5.0	17.2	1.3	17.5
1979	73.0	56.3	21.8	5.0	17.4	1.3	18.2
1980	69.5	44.5	25.3	5.0	16.6	1.3	21.8
1981	66.5	40.0	24.5	5.0	17.2	1.3	n.a.

Source: Rubber Statistical Bulletin

Ghana and Central African Republic

Two minor NR producers for which a modest increase may be envisaged.

Cameroon

As for other African countries the latter half of the seventies was accompanied by declining NR production. Due to some new planting this downward trend may level-off and some improvement may be expected in the long-run.

Ivory Coast

The only country where NR production, though at a modest level, has been growing, is Ivory Coast. Further increases at the same rate seem likely in the decades ahead.

Latin America

Brazil

Production of NR in Latin America is coming largely from Brazil, the origin of Hevea Brasiliensis. Whereas its NR is still for an important part coming from wild trees, a scheme has been initiated to increase NR production. Since 1974 production has increased by 50 percent (table 8.15) and further expansion may be foreseen.

Other Latin America

Other countries have shown increasing NR output in the last decade and it is expected that this trend will continue.

Table 8.15 *Estimated production of NR (1,000 tonnes) in Latin America*

Year	*Brazil*	*Other Latin America*
1960	23.1	7.0
1961	22.7	7.0
1962	21.6	7.0
1963	20.6	7.0
1964	28.3	7.0
1965	29.3	7.0
1966	24.4	7.0
1967	21.5	7.0
1968	23.0	7.0
1969	24.0	7.0
1970	25.0	7.0
1971	24.2	8.0
1972	25.8	9.0
1973	23.4	10.0
1974	18.6	11.0
1975	19.4	12.0
1976	20.3	17.0
1977	22.6	18.0
1978	23.7	19.0
1979	25.0	19.0
1980	27.8	20.0
1981	30.3	19.0

Source: Rubber Statistical Bulletin

8.6 PROJECTIONS OF NATURAL RUBBER SUPPLY

In the previous sections of this chapter, NR production has been analyzed for all NR producing countries of the world. The countries can be divided into three groups:

(i) - countries for which a vintage approach was possible: Peninsular Malaysia (estates and smallholdings), Indonesia (estates and smallholdings) and Thailand

(ii) - countries for which an econometric equation could be estimated: East-Malaysia (Sabah and Sarawak) and Philippines

(iii) - the other NR producing countries, for which projections have already been formulated in the sections 8.4 and 8.5.

In this section projections for all countries will be presented, together yielding the world picture of future NR supply.

A category of variables which is used for the countries of group (i) is the group of technical progress functions. For these functions, a linear extrapolation is used. There are two exceptions where assumptions have been made, based on various sources: Indonesian smallholdings and Thailand.

An in some cases important factor used for the countries of groups (i) and (ii) was the influence of the price of NR. However, in almost all equations where this price has been included, it was in the form of a price ratio (P_t^N/P_{t-1}^N). It is therefore not surprising that various patterns of prospective developments in the price of NR do not affect the long-term trend, if the other explanatory variables are given. It is this trend which will be a key factor in chapter 9, where price influences on a year to year basis will be included for world aggregates.

At this juncture, no investment function for NR has been included. Ideally, possible high levels of P_t^N around 1985 should lead to increased planting activities in the second half of the 1980's, resulting in an upswing in production from around 1995 onwards. Such a policy would then result as a feedback from price developments as projected in chapter 9. Because the policies will not be very clear due to exogenous (government policy) influences, and because the number of alternative policies is quite unlimited, this subject will only be treated qualitatively in chapter 9.

The last group of variables on which thus assumptions for the future must be made consists of those variables concerning new planting, replanting and uprooting of land with rubber trees. In this chapter one set of planting policies and their effect on future production possibilities will be presented. Any alternative may be tested in the future. The hypothetical policies are as described in table 8.17.

For 5-year periods the projections of NR supply are given in table 8.18, partly based on the projections of table 8.16. A graph for 5-year periods is shown in figure 8.4. These results are consistent with the background information given in the previous sections: Thailand is making a major leap forward, Indonesia is following later and Malaysian smallholdings are rather constant while estate production shows a decrease. The three major Asian producers are increasing their share in world NR production.

In the next chapter, the effects of such a production policy on the market conditions for NR will be analyzed and discussed.

Table 8.16 *Projections of NR production (1,000 tonnes) for countries and regions other than Malaysia, Indonesia and Thailand*

	1985	*1990*	*1995*	*2000*
Sri Lanka	135	145	160	170
India	175	200	225	250
Burma	22	25	30	38
Philippines	94	118	141	165
Vietnam	60	80	110	150
Kampuchea	30	50	70	100
China	125	150	175	200
Other Asia	8	10	12	15
Asia	649	778	923	1,088
Liberia	60	60	60	60
Nigeria	60	60	60	60
Zaïre	25	25	25	25
Ghana	6	7	8	9
Cameroon	15	20	25	25
Central African Rep.	1	2	2	2
Ivory Coast	25	30	35	40
Africa	192	204	215	221
Brazil	38	45	50	55
Other Latin America	25	30	35	40
Latin America	63	75	85	95

Table 8.17 *Assumed planting policies for natural rubber (in 1,000 ha) in Malaysia, Indonesia and Thailand*

			1985	1990	1995	2000
Malaysia	estates	T	475	475	475	475
		R	13	15	15	15
	smallholdings	T	1,253	1,353	1,453	1,553
		N	20	20	20	20
		R	25	35	35	35
		AE	1	1	1	1
Indonesia	public estates	T	205	230	255	280
		N	7	7	7	7
		R	5	5	5	5
	private estates	T	260	270	280	290
		N	5	7	7	7
		R	3	3	3	3
	smallholdings	T	1,920	1,970	2,020	2,070
		N	20	20	20	20
		R	50	50	50	50
Thailand		T	1,550	1,600	1,650	1,700
		N	12.5	12.5	12.5	12.5
		R	40	40	30	30

Notes: T = total area
R = replanting
N = new planting
AE = area from estates

Table 8.18 *Projections of supply of natural rubber (in 1,000 tonnes), see text*

		1985	1990	1995	2000
Malaysia	estates	532	466	439	456
	smallholdings	910	913	974	1,096
	Peninsular, total	1,443	1,379	1,412	1,552
	Sabah	29	28	28	27
	Sarawak	29	28	27	26
	East, total	57	56	54	53
	total	1,500	1,435	1,466	1,604
Indonesia	estates	348	350	401	470
	smallholdings	808	838	919	997
	total	1,156	1,188	1,320	1,466
Thailand		784	1,056	1,376	1,674
Total three major producers		3,440	3,679	4,163	4,745
Other Asian countries		649	778	923	1,088
Total Asia		4,089	4,457	5,086	5,833
Africa		192	204	215	221
Latin America		63	75	85	95
World total		4,344	4,736	5,385	6,148

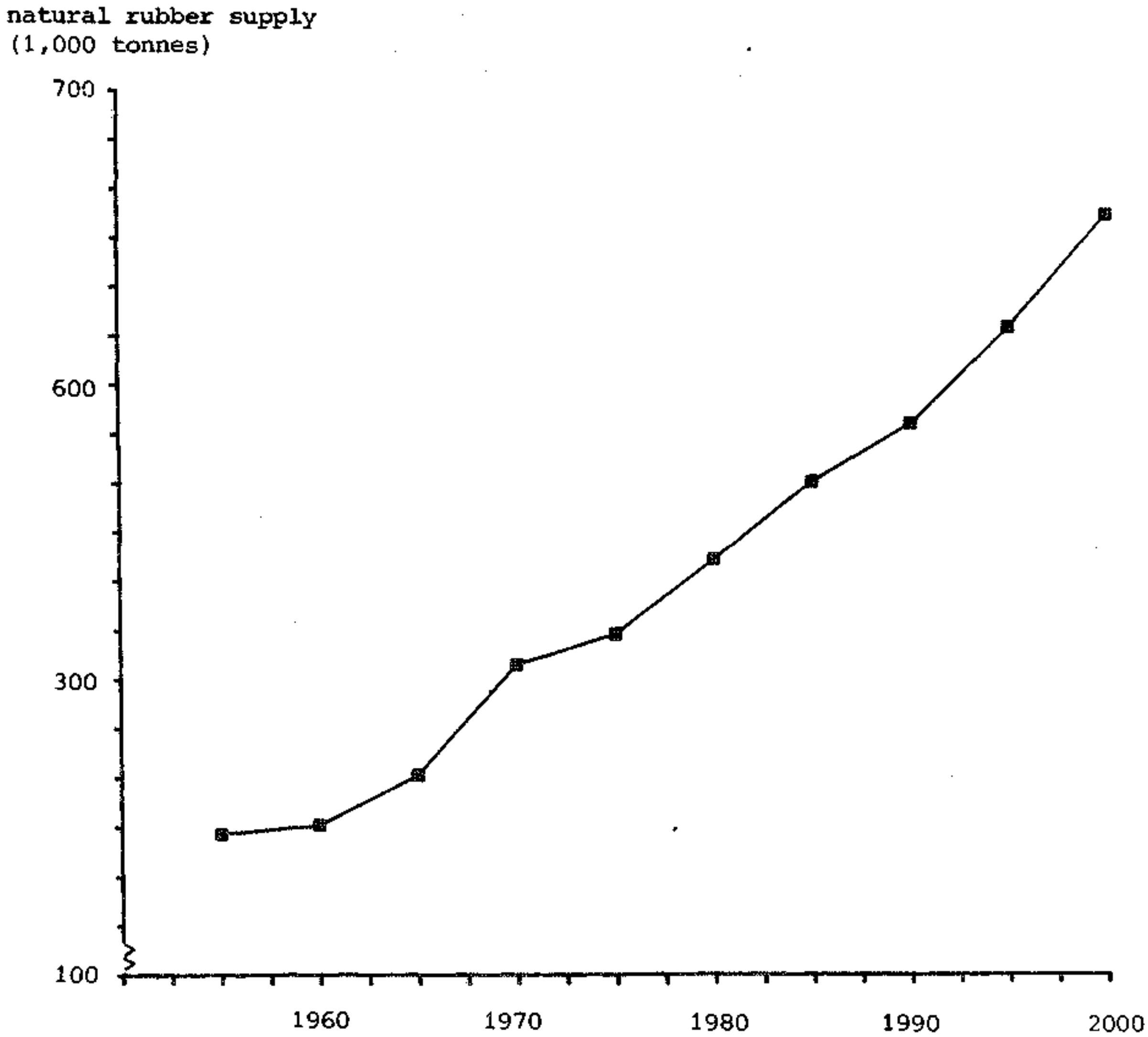


Figure 8.4 *Estimated and projected supply of natural rubber (in 1,000 tonnes)*

9. MARKET IMPLICATIONS FOR NATURAL RUBBER

Total demand for rubber is divided between natural rubber (NR) and synthetic rubber (SR). How has this division been determined in the past and what will be the share of NR and SR in the future? After some historical information in section 9.1, our own analysis and model will be discussed in 9.2. Projections are presented in 9.3.

9.1 HISTORICAL DEVELOPMENTS AND GENERAL BACKGROUND

Since SR came to prominence in the second World War, mainly because of blocked NR supply lines, it has taken an ever-increasing share of world rubber demand.

The share of NR in total rubber demand, although different between countries, declined in the 1960's, levelled off in the early 1970's, increased again slightly after 1973 and seems to have stabilized since, at a level of approximately 30 percent for the world at large. Factors influencing the shares of the two broad types of rubber can be divided into a few partly overlapping groups which will be briefly discussed here.

The first aspect can be called technical factors. Whereas NR was the only important rubber in the first half of this century, ground has been lost to synthetic rubber owing to technical improvement of SR, be it general purpose or special purpose rubber. Production of NR also has achieved technical progress, especially in the development of standard qualities, which makes it easier to process. There is space for substitution between NR and SR but experts have different opinions on the size of this area of substitution: NR and synthetic polyisoprene (IR) which are close substitutes, can only partly be a substitute for other SR.

Secondly, there are the economic factors, the most important one being relative raw material prices. These together with other costs (e.g. processing transportation) and import and export duties constitute relative input costs. The distance to travel by NR and the high level of vertical integration in the SR industry between SR producers and rubber goods' producers are clear advantages to SR.

A more recent aspect is the environmental issue: production of NR is not as polluting as SR. Furthermore, NR is an agricultural product without strong physical production limitations whereas SR has oil as its main feedstock, which may become more scarce in the future. These aspects influence expectations, production and investment decisions and, therefore, the future share of both types of rubber.

Above we already touched upon long-run availability of oil for SR production. Limited availability of NR due to production constraints in the 1950's and 1960's undoubtedly influenced the share of NR in world consumption. Whether NR supply limitations will reduce a possible market share in the future depends on production decisions being made within the next few years.

Short-run availability of NR has both geographical and political aspects. The geographical distance between NR producers and major consumers requires stocks of NR in consuming countries, that are relatively larger than those of SR, which can be bought next-door. Obviously this makes NR more expensive. Moreover, it makes NR more subject to political uncertainties, not only in the country of origin, but all along the searoutes. Availability in times of political crises can only be partly solved by stock-piling. The desire for self-sufficiency in rubber may have been an additional reason in Western countries for the expansion of SR facilities in the 1950's and 1960's. It most certainly was the reason for the construction of large SR plants and more specifically of synthetic isoprene (IR) plants in European Centrally Planned Economies. Balance-of-payments considerations in these countries usually are more important than relative costs or performance. As a result the share of NR in this region is extremely low.

Finally, there is the composition aspect. In assessing the share of NR at the macro level it is necessary to take into account the effects of the micro level composition of the total rubber end-uses, e.g. the shift from conventional tires to radial tires. These effects are largely autonomous and should not be confused with technical and economic effects in assessing and projecting the share of the various types of rubber in total rubber demand.

A broad division which has been used in this study is the split into the tire sector and the non-tire sector. Some data on NR-shares in these two sectors are given in tables 9.1 and 9.2 respectively. It is clear that developments in NR-shares over the past two decades are quite different for the two sectors and show a great deal of similarity between countries.

Table 9.1 *Percentage share of natural rubber in total rubber consumption in the tire sector*

	USA	*United Kingdom*	*France*	*Germany, F.R.*	*Italy*	*Japan*	*Brazil*	*Canada*
1960	32.6	53.3	60.8	54.9	62.7	77.6	n.a.	39.7
1965	27.2	46.0	47.8	40.0	48.0	51.8	44.6	31.0
1970	24.5	41.8	43.5	36.2	42.1	38.6	34.8	27.9
1971	23.6	42.1	42.4	38.3	43.2	39.1	35.4	28.3
1972	24.1	40.9	40.7	37.7	42.2	39.1	33.6	29.5
1973	25.5	39.8	40.2	39.0	41.0	38.6	33.2	28.8
1974	28.5	42.2	40.3	40.7	40.9	40.0	31.8	n.a.
1975	29.4	44.8	41.8	40.5	41.6	36.5	30.5	n.a.
1976	28.7	42.7	42.1	41.0	41.4	36.1	30.4	n.a.
1977	29.9	43.2	41.4	41.3	39.1	36.2	31.7	n.a.
1978	30.0	41.6	42.7	42.1	39.2	37.7	30.9	n.a.
1979	30.4	42.4	43.1	42.4	41.0	38.9	30.4	n.a.
1980	28.8	45.7	44.3	43.7	42.0	39.2	30.9	n.a.

Source: Rubber Statistical Bulletin

Table 9.2 *Percentage share of natural rubber in total rubber consumption in the non-tire sector*

	USA	*United Kingom*	*France*	*Germany, F.R.*	*Italy*	*Japan*	*Brazil*	*Canada*
1960	36.7	69.2	55.3	62.3	49.2	69.8	n.a.	36.3
1965	21.3	55.6	39.4	47.1	37.9	55.0	33.0	30.4
1970	19.1	40.8	28.1	35.7	30.5	33.9	21.2	24.8
1971	17.7	38.2	25.4	31.8	29.9	32.6	20.3	16.9
1972	17.6	36.1	24.9	31.8	27.2	29.5	19.5	17.6
1973	17.4	33.2	25.2	26.4	25.8	24.4	14.9	16.5
1974	18.0	33.1	23.6	25.3	26.0	24.6	16.9	n.a.
1975	18.0	33.5	25.1	30.8	28.7	26.7	15.7	n.a.
1976	17.1	26.3	26.1	22.7	30.8	24.5	15.5	n.a.
1977	15.1	25.7	23.3	17.6	25.8	24.6	16.1	n.a.
1978	13.3	22.0	20.6	20.1	22.6	24.1	14.4	n.a.
1979	12.1	23.2	19.9	16.9	23.0	20.9	16.2	n.a.
1980	n.a.	24.1	19.8	18.2	23.8	20.9	15.0	n.a.

Source: Rubber Statistical Bulletin

The tire sector (table 9.1) outside North-America has never reached the low NR-shares of under 30 percent in the sixties. This may have been caused by large scale production of SR, with partly domestically produced feedstock. Besides, SR production was in many cases vertically integrated with the tire industry. Then, in the second half of the sixties the penetration of the radial tire became significant in Europe, thus partly creating a return to NR use. In North-America and Japan the shift to radial tires only became important in the seventies, coinciding with some withdrawal from SR because of higher prices after the oil-crisis in 1973. Europe and Japan now seem to have stabilized at around 40-45 percent with North-America and Brazil some 10 percentage points lower.

Developments in the non-tire sector (table 9.2) are quite different. A continuing decline can be spotted in all countries although the oil-crisis has created some improvement for NR for a year or two. Reasons for this decline are availability and price of NR and the increasing influence of special purpose synthetic rubbers. Again, NR-shares in North-America and Brazil are somewhat lower than in Europe and Japan. Stabilization can not be envisaged as yet.

9.2 MODELING THE SHARE ANALYSIS

Specification of the model

a. *Total demand for rubber*

In chapter 6 total demand for rubber has been derived both for the tire sector and for the non-tire sector, these demand levels were determined by such variables as income, population, passenger car- and commercial vehicle-ownership, driving distance and quality of tires.

In doing so, it has been assumed implicitly that it is most unlikely that supply of various rubbers and their respective prices would affect demand for rubber in the tire sector and in the non-tire sector. In view of the still rather low degree of capacity utilization in the synthetic rubber industry and the possibility of increasing capacity in a year or two, SR can fill any supply gap (if its use is technically feasible in view of the desired characteristics of the end-product).

Further, it may be assumed that over a very wide price-range prices of NR and SR will not affect total rubber demand in the tire sector or in the non--tire sector. The reasons for this price-inelasticity are:

- the price of the rubber end-product (e.g. a set of tires) is small compared to cost of using or buying the product of which the rubber end--product is an integral part (e.g. driving a car)
- the cost of the rubber input is relatively low compared to the price of the end-product (e.g. rubber parts of engines)
- substitutes are not available or have, to a large extent, the same cost structure as rubber (e.g. plastics).

It has therefore been assumed for this sub-model that:

- total rubber demand in the tire sector is predetermined
- total rubber demand in the non-tire sector is predetermined.

This is the basis for the sub-model on NR-shares.

b. *The NR-share in the tire sector, some technical aspects*

It has already been stated in section 9.1 that quality improvements in SR allowed SR to take a major part of rubber consumption in the tire sector. However, this move has largely come to a halt because of the penetration of radial tires. Possible further penetration of synthetic isoprene rubber, substituting NR, will be discussed in section 9.3.

The shift to radial tires has strongly influenced the share of NR because of relatively large NR requirements in the sidewalls of radial tires. The share of NR may therefore be some 20-30 percent larger in a radial tire when compared to a conventional tire. This implies that a change in the percentage of radial tires will have autonomous effects on the NR-share in the tire sector. It is possible thus to derive an expected level of the NR-share in the tire sector.

The actual share of NR in the tire sector, based e.g. on cost minimization, may be different from the expected share. The reason may be that it is better to use a different mix because of prices and supply of inputs. However, limited flexibility in changing to a different production process restricts the possible difference. This flexibility will even be lower if the share of NR is very low, indicating a limited scope for further substitution.

c. *The NR-share in the non-tire sector, some technical aspects*

Similar remarks as for the tire sector may be made for the non-tire sector. However, the composition of the non-tire sector is too complex to derive autonomous movements in the share of NR in the non-tire sector. For want of better evidence, one may now derive an expected share of NR in the non-tire sector which equals last year's actual share.

Again, the actual share of NR in the non-tire sector may differ from the expected share e.g. due to cost consideration. However, the width of the band in this case may be different from that for the tire sector, resulting in different constraints.

d. *Optimal shares, technical and economic factors*

Having derived what the shares are expected to be and in which range actual shares must lie, it is now necessary to develop a criterion for future levels of the shares. Expected cost minimization, based on prices in the past and on total demand, is a proper criterion, where industry fixes the shares on the basis of prices in the previous year.

Minimization will in general give optimal values at the extremes of the constraints. However, if cost differences are minor, there will be little stimulus to introduce dramatic technical changes.

e. *Synthetic rubber prices*

Since it is beyond the scope of this study to include various types of SR, it has been decided to only incorporate in the market share analysis the most important synthetic general purpose rubber which as such is the most relevant competitor or counterpart of NR, namely styrene butadiene rubber (SBR).

List prices of SBR can be related to prices of feedstocks and to inflation. Actually paid prices of SBR (P^S) have a discount over list prices. These discounts may be up to 30 percent, depending on the degree of capacity utilization of the SR industry, taking into account NR supply. It is not feasible in this study to do such an analysis of the SR industry. For the sample period 1960-1980, data on P^S have been collected from various industry sources. For the future P^S is also exogenous and will be assumed to follow certain scenarios.

f. *Natural rubber prices*
Out of a range of types of NR, RSS1 has been selected as representative, based on the price at the New York market. In the analysis prices of other types and at other markets (Singapore, London, Kuala Lumpur, etc.) are mainly related to this RSS1, New York price (P^N). It is recognized that RSS3 might have been chosen as well; this price is strongly correlated to the RSS1 price.

Two major groups of factors influence price developments of NR. First, developments in P^S will have a strong direct effect on P^N. Price discrepancies between P^N and P^S therefore tend to be reduced as long as there is more NR than the minimum requirement. This has already been discussed in chapter 7. Secondly, developments in the demand and supply position of NR will undoubtedly influence P^N. A suitable indicator for this is NR inventories, expressed as a ratio to the trend in NR production.

g. *Rubber supply*

Synthetic rubber supply is not included, because, as has already been argued above, there are no real capacity constraints. However, natural rubber supply, being largely capacity determined through tappable area, quality of trees and age distribution of trees, has only little scope for adjustment in the short-run (see chapters 7 and 8). As an aggregate approximation, it is supposed to be determined by "normal production" with some price influence.

Ideally, at this place all the country models for NR supply should have been called in. However, this would mean an enormous computational effort. Therefore, the country models are used to obtain the trend values for what may be called "normal production". Because only price changes and not price levels proved to be of influence (except for some effect in the case of Malaysian smallholdings (cf. chapter 8), the error introduced by this approach is minor. For world aggregate supply, the price-ratio elasticity is estimated separately at 0.08.

Estimation of the model

The model specified above is a dynamic model which cannot be rewritten as a (non-)linear econometric model because of the aspects of cost minimization under constraints. This implies that standard regression analysis is not feasible. The method adopted for the estimation of this model is to use dynamic simulation and to compare the results with the reality of the sample period. This, of course, is a very severe test because many models do not behave properly and some even explode over a 21-year sample period using dynamic simulation.

A number of variables is exogenous to the sub-model of this chapter. In the estimation procedure actual data were needed. It was not possible to obtain data on two important series: demand for rubber in the tire sector and demand for rubber in the non-tire sector. However, using the properly disaggregated data for eight countries, United States, Canada, Germany F.R., France, United Kingdom, Italy, Japan and Brazil (table 9.3) it became clear that these eight countries cover a large part of world rubber consumption (col. (3) and (4)) and that the tire sector takes a very stable share of about 59 percent of total rubber consumption for these countries (col. (7)). It is realistic to assume a slightly lower contribution of the tire sector for the rest of the world, say 50 percent (col. (8)). Now, excluding China, world rubber consumption can be split into tire rubber demand (col. (10)) and non-tire rubber demand (col. (11)).

Data on other variables which are exogenous to this sub-model are presented in table 9.4. On the basis of numerous sources, a world share of radial tires has been computed (col. (1)). Similarly an approximation for a (discounted) price of SBR1500 has been developed (col. (7)). From the Rubber Statistical Bulletin, data on NR supply (S^N), NR government stockpile deliveries ($GSPD$) and NR demand of China (D^{NC}) have been obtained (columns (2), (3), (4) and (5) of table 9.6).

The R^2 with respect to NR demand is 0.986 and the R^2 relating to NR prices is 0.954. For the crucial variables D_t^N and P_t^N, actual data and simulation results are shown in table 9.5. For D_t^N the relative residuals are less than 4.5 percent. Residuals are relatively larger for P_t^N. The largest relative residual occurs in 1972. High level economic growth in the late sixties and early seventies created a commodity boom in 1972 causing all commodity prices to increase dramatically. The model predicts an increase by some 25 percent but in reality, for certain reasons which cannot be captured in this analysis, the increase in price was postponed to November 1972. Thus leaving P_t^N unchanged with respect to 1971 in US \$, while a decrease may be noticed at the Singapore market. An outlier was the low price in 1968 which has been predicted at a higher level. From the other 19 years, 15 estimations were less than 10 percent different from reality.

Simulation results for some other variables are shown in table 9.6. It is interesti to see the development in R_t^T. The rapid decline in the early sixties slowed down from 1962 to 1970 because of the introduction and penetration of the radial tire in Europe. A similar development in North-America and Japan caused the NR-share to stabilize at around 0.36.

Table 9.3 *Rubber consumption in the tire and the non-tire sector (1,000 tonnes)*

	(1) D^{T8}	(2) D^{O8}	(3) D^{8}	(4) D^{W}	(5) D^{China}	(6) D^{R}	(7) D^{T8}/D^{8}	(8) D^{TR}/D^{R}	(9) D^{TR}	(10) $D^{T,W-C}$	(11) $D^{O,W-C}$
	—	—	(1)+(2)	—	—	(4)-(3)-(5)	(1)/(3)	assumed	(6)*(8)	(1)+(8)	(4)-(10)
1960	1744.0	1178.5	2922.4	4495.3	110.0 a)	1462.6	0.597	0.5	731.3	2475.0	2019.7
1961	1741.9	1201.6	2943.6	4710.0	120.0 a)	1646.4	0.592	0.5	823.2	2565.1	2144.9
1962	1911.4	1336.1	3247.5	5115.0	130.0 a)	1737.5	0.589	0.5	868.8	2780.2	2334.9
1963	2001.8	1407.6	3409.4	5351.0	140.0 a)	1801.6	0.587	0.5	900.8	2902.6	2448.4
1964	2160.7	1517.1	3677.8	5825.0	157.5	1989.7	0.587	0.5	994.9	3155.6	2669.5
1965	2328.2	1555.1	3883.3	6187.5	170.0	2134.2	0.600	0.5	1067.1	3395.3	2792.2
1966	2505.1	1695.9	4201.0	6677.5	190.0	2286.5	0.596	0.5	1143.3	3648.4	3029.2
1967	2485.8	1724.1	4209.9	6805.0	205.0	2390.1	0.590	0.5	1195.1	3680.9	3124.2
1968	2887.6	1929.7	4817.3	7650.0	225.0	2607.7	0.599	0.5	1303.9	4191.5	3458.6
1969	3180.2	2090.0	5270.2	8267.5	245.0	2752.3	0.603	0.5	1376.2	4556.4	3711.2
1970	3165.2	2199.5	5364.7	8625.0	255.0	3005.3	0.590	0.5	1502.7	4667.9	3957.2
1971	3425.9	2254.7	5680.6	9277.5	260.0	3336.9	0.603	0.5	1668.5	5094.4	4183.2
1972	3669.5	2412.0	6081.5	9960.0	260.0	3618.5	0.603	0.5	1809.3	5478.8	4481.3
1973	3836.8	2800.0	6636.8	10977.5	270.0	4070.7	0.578	0.5	2035.4	5872.2	5105.4
1974	3773.1	2480.2	6062.9	10967.5	210.0	4694.6	0.622	0.5	2347.4	6120.4	4847.1
1975	3474.8	2289.8	5764.6	10395.0	280.0	4350.4	0.603	0.5	2175.2	5650.0	4745.0
1976	3648.8	2715.0	6363.8	11420.0	300.0	4756.2	0.573	0.5	2378.1	6026.9	5393.1
1977	4097.8	2895.7	6993.5	12330.0	350.0	4986.5	0.586	0.5	2493.3	6591.1	5739.0
1978	3979.3	2907.7	6887.0	12495.0	385.0	5223.0	0.578	0.5	2611.5	6590.8	5904.2
1979	4067.1	3011.7	7078.8	12995.0	430.0	5486.2	0.575	0.5	2743.1	6810.2	6184.8
1980	3744.4	2647.1 p)	6391.5 p)	12425.0	450.0	5583.5	0.586 p)	0.5	2791.8	6536.2	5888.9

Notes:

D^{T8} = rubber consumption, tire sector, eight countries (United States, Canada, Germany F.R., France, United Kingdom, Italy, Japan, Brazil).

D^{O8} = rubber consumption, non-tire sector, eight countries (ditto).

D^{8} = total rubber consumption, eight countries (ditto).

D^{W} = total rubber consumption, world.

D^{China} = total rubber consumption, China.

D^{R} = total rubber consumption world excl. the eight countries (ditto) and China

D^{TR} = ditto in the tire sector.

$D^{T,W-C}$ = total rubber consumption, tire sector, world excl. China.

$D^{O,W-C}$ = total rubber consumption, non-tire sector, world excl. China.

a) = assumed

p) = provisional, as these figures have been used for the estimation procedure, no updated figures are presented here.

Source: Rubber Statistical Bulletin for the columns *(1)*, *(2)*, *(4)* and *(5)*.

Table 9.4 *Various data on the world rubber economy*

	R^R	S^N	*GSPD*	S^N + *GSPD*	D^{NC}	D^N	P^N	P^S
1960	.000	2047.5	162.5	2210.0	90.0	2098.0	.841	.540
1961	.000	2160.0	30.0	2190.0	100.0	2161.5	.650	.530
1962	.000	2187.5	67.5	2255.0	110.0	2255.5	.630	.520
1963	.010	2132.5	97.5	2230.0	120.0	2265.5	.579	.500
1964	.030	2352.5	103.2	2455.7	130.0	2380.0	.557	.480
1965	.050	2352.5	121.6	2474.1	140.0	2447.5	.566	.460
1966	.070	2392.5	159.1	2551.6	155.0	2542.5	.521	.430
1967	.095	2522.5	100.8	2623.3	165.0	2535.0	.439	.410
1968	.120	2685.0	73.9	2758.9	180.0	2780.0	.437	.390
1969	.150	2995.0	37.8	3032.8	195.0	2910.0	.578	.370
1970	.190	3102.5	22.8	3125.3	207.5	2990.0	.463	.360
1971	.225	3085.0	18.1	3103.1	210.0	3092.5	.399	.360
1972	.280	3120.0	48.2	3168.2	210.0	3230.0	.402	.360
1973	.330	3505.0	64.9	3569.9	217.5	3402.5	.785	.420
1974	.370	3445.0	75.7	3520.7	217.5	3517.5	.868	.730
1975	.410	3315.0	14.7	3329.7	225.0	3367.5	.659	.700
1976	.455	3585.0	3.0	3588.0	240.0	3505.0	.872	.700
1977	.495	3625.0	2.0	3627.0	280.0	3715.0	.917	.750
1978	.530	3755.0	0.0	3755.0	300.0	3725.0	1.108	.800
1979	.560	3860.0	0.0	3860.0	335.0	3870.0	1.423	1.120
1980	.600	3820.0	0.0	3820.0	340.0	3785.0	1.625	1.320

Notes:
- R^R = share of radial tires
- S^N = supply of NR, 1,000 tonnes
- *GSPD* = government stockpile deliveries of NR, 1,000 tonnes
- D^{NC} = demand for NR in China, 1,000 tonnes
- D^N = world demand for NR, 1,000 tonnes
- P^N = price of NR, RSS1, New York, US \$ per kg
- P^S = price of SBR, US \$ per kg.

Table 9.5 *Data on dynamic estimation results on demand for NR in 1,000 tonnes (D^N and $\hat{D}^N$) and on price of NR in US \$ per kg (P^N and $\hat{P}^N$)*

	D^N	$\hat{D}^N$	$D^N - \hat{D}^N$	$\frac{D^N - \hat{D}^N}{D^N}$	P^N	$\hat{P}^N$	$P^N - \hat{P}^N$	$\frac{P^N - \hat{P}^N}{P^N}$
1960	2098.0	2101.6	-3.61	-.00172	.84	.76	.08	.09158
1961	2161.5	2104.2	57.27	.02650	.65	.66	-.01	-.01024
1962	2255.5	2190.8	64.67	.02867	.63	.61	.02	.03304
1963	2265.5	2222.0	43.51	.01920	.58	.57	.01	.01137
1964	2380.0	2356.8	23.23	.00976	.56	.55	.00	.00573
1965	2447.5	2441.7	5.79	.00236	.57	.51	.05	.09274
1966	2542.5	2586.3	-43.82	-.01723	.52	.55	-.03	-.05607
1967	2535.0	2559.5	-24.47	-.00965	.44	.50	-.06	-.14517
1968	2780.0	2795.7	-15.69	-.00564	.44	.57	-.13	-.29335
1969	2910.0	2926.1	-16.06	-.00552	.58	.55	.03	.05051
1970	2990.0	2964.6	25.36	.00848	.46	.45	.02	.03267
1971	3092.5	3113.2	-20.74	-.00671	.40	.45	-.05	-.12345
1972	3230.0	3285.6	-55.62	-.01722	.40	.55	-.15	-.38046
1973	3402.5	3506.5	-104.03	-.03057	.79	.67	.12	.15008
1974	3517.5	3443.2	74.32	.02113	.87	.87	-.01	-.00698
1975	3367.5	3222.3	145.16	.04311	.66	.72	-.06	-.09464
1976	3505.0	3551.0	-45.96	-.01311	.87	.77	.10	.11526
1977	3715.0	3862.1	-147.12	-.03960	.92	.98	-.06	-.06429
1978	3725.0	3839.2	-114.19	-.03066	1.11	1.10	.01	.00779
1979	3870.0	3913.6	-43.62	-.01127	1.42	1.43	-.01	-.00497
1980	3785.0	3711.9	73.10	.01931	1.63	1.53	.09	.05771

Table 9.6 *Simulation results for some other variables*

	R^T	R^O	D^{NT}	D^{NO}	D^N	S^N + *GSPD*	P^S	P^N
1960	.42	.48	1047.8	963.8	2101.6	2047.5	.54	.76
1961	.41	.45	1045.5	958.7	2104.2	2160.0	.53	.66
1962	.39	.42	1095.8	985.1	2190.8	2187.5	.52	.61
1963	.39	.40	1119.4	982.6	2222.0	2132.5	.50	.57
1964	.38	.38	1202.9	1023.9	2356.8	2352.5	.48	.55
1965	.38	.37	1278.8	1023.0	2441.7	2352.5	.46	.51
1966	.37	.35	1363.4	1068.0	2586.3	2392.5	.43	.55
1967	.37	.33	1354.6	1039.9	2559.5	2522.5	.41	.50
1968	.36	.32	1523.4	1092.3	2795.7	2685.0	.39	.57
1969	.36	.30	1630.9	1100.2	2926.1	2995.0	.37	.55
1970	.35	.28	1656.5	1100.6	2964.6	3102.5	.36	.45
1971	.35	.26	1798.4	1104.9	3113.2	3085.0	.36	.45
1972	.36	.25	1951.2	1124.4	3285.6	3120.0	.36	.55
1973	.36	.24	2087.5	1201.6	3506.5	3505.0	.42	.67
1974	.35	.22	2156.1	1069.6	3443.2	3445.0	.73	.87
1975	.35	.21	1995.5	1001.9	3222.3	3315.0	.70	.72
1976	.36	.21	2183.9	1127.0	3551.0	3585.0	.70	.77
1977	.37	.20	2416.7	1165.4	3862.1	3625.0	.75	.98
1978	.36	.19	2402.5	1136.7	3839.2	3755.0	.80	1.10
1979	.36	.18	2453.8	1124.8	3913.6	3860.0	1.12	1.43
1980	.36	.17	2353.4	1018.5	3711.9	3820.0	1.32	1.53

Notes:
R^T = NR-share in the tire sector
R^O = NR-share in the non-tire sector
D^{NT} = demand for NR in the tire sector, 1,000 tonnes
D^{NO} = demand for NR in the non-tire sector, 1,000 tonnes
S^N = supply of NR ("exogenous"), 1,000 tonnes
GSDP = stockpile deliveries of NR ("exogenous"), 1,000 tonnes
P^S = price of SR ("exogenous"), SBR1500, US \$ per kg
P^N = price of NR, RSS1, New York, US \$ per kg.

9.3 PROJECTIONS OF NR MARKET SHARE AND CONCLUSIONS ON OPTIMAL PRODUCTION POLICIES

General aspects

In section 9.2 a description has been given of the analysis concerning the interaction between demand and supply of NR in the period 1960-1980. The structure of the relationship between demand, supply and prices of NR has been represented in a model. This model, with the estimated values of the parameters, is used to obtain projections of future market conditions for NR and, subsequently, to draw conclusions about the effects of certain production policies for NR.

Supply projections have been presented in section 8.6, as far as the trend is concerned. Quantities have been presented in table 8.18. These trend projections are used as an input to the market share analysis. From the analysis it will be concluded whether the production policy should be adjusted or not. In only giving NR supply trend projections and actual supplies corrected for supply elasticities in each year, a complicating factor has been disregarded. At the present moment, an unknown quantity of rubber is held by the INRO buffer stock. This quantity will no doubt be released when NR prices rise to the level indicated in the Agreement. This would change the NR supply situation and thereby the value of the other variables in the eighties.

It is very difficult, if not utterly impossible, to make a forecast of the price of synthetic rubber. Three aspects are important:

1. some inflation must be included, as the whole model is in nominal prices
2. under conditions of overcapacity, SR is sold below its cost price; in the long-run, however, production costs will have to be recovered by an increase of P^S
3. an increase in oil prices, following an economic recovery, will result in higher cost prices of SR, and thus in an additional upswing of P^S.

With a view to these considerations, three scenarios for P^S have been developed as presented in table 9.7. They are not drawn up with the illusion of really covering future development in SBR prices. A regular increase to cover inflation is added yearly (P1). The alternative prices P2 and P3 accelerate after 1985, P2 representing a situation of better capacity utilization, and P3 including an increase in the price of feedstocks.

Table 9.7 *Scenarios for P_t^S, the price of synthetic rubber (US $ per kg)*

	scenarios		
	P1	*P2*	*P3*
1981	1.30	1.30	1.30
1982	1.10	1.10	1.10
1983	1.25	1.25	1.25
1984	1.30	1.30	1.50
1985	1.40	1.50	1.80
1986	1.55	1.90	2.10
1987	1.70	2.30	2.30
1988	1.85	2.45	2.50
1989	2.00	2.60	2.70
1990	2.15	2.75	2.90
1991	2.30	2.90	3.20
1992	2.45	3.10	3.50
1993	2.60	3.30	3.80
1994	2.75	3.50	4.10
1995	2.90	3.70	4.40
1996	3.05	3.90	4.60
1997	3.20	4.10	4.80
1998	3.35	4.30	5.00
1999	3.50	4.50	5.20
2000	3.65	4.70	5.40

At the demand side, three economic growth scenarios have resulted in three series of projections of demand for rubber in the tire sector and in the non-tire sector. Below, for each demand scenario G1, G2 and G3, the projection results will be discussed.

The low-growth demand scenario: G1

As a rapid rise in feedstock price under the low-growth scenario is highly unlikely, the low-growth demand scenario is combined with the synthetic rubber price scenarios P1 and P2, and gives as results the figures presented in tables 9.8 and 9.9 respectively. In drawing conclusions from these tables the following considerations need to be taken into account.

The assumption is that the price of SBR is exogenous. Indeed, in the long--run, synthetic rubber needs to be sold at a price which about equals the cost price; if necessary, capacity adjustments will take care of the requirement of profitability. The price of feedstocks and other cost components determine the long-run price level of SR.

In the short-run, however, developments in the demand-supply position for rubber may influence the price actually paid for SR. For the sample period an attempt has been made to include the price of SR after discount. In order to include these short-term aspects in the projection part of this study, it would be necessary to have a better insight in the various cost components of synthetic rubber as well as in the degree to which SBR producers are prepared to deviate from the list price of SR in combination with under-utilization of capacity. This requires a separate analysis, which cannot be included in the present study in view of its limited scope. The consequence, however, is that, wherever P_t^S is used for projection purposes, it is the exogenously given trend and not the price of SR as affected by market developments. These figures for projections of P_t^S are the elements of the market share analysis for the years ahead. In view of the above considerations, the projected values in tables 9.8ff may need some revision after inclusion of short-term influences on P_t^S, in particular when the price of SR is far above the price of NR (cf. tables 9.8 and 9.9 , for the second half of the 1990's).

While acknowledging the limited effects of the two scenarios P1 and P2 on the long-term future for NR, it is seen that the sudden jump in P_t^S in 1985-1987 (table 9.9) creates an increase in $R_t^{T'}$ and R_t^O at the end of the 1980's, which, in turn, cause P_t^N to increase more in the 1990's and R_t^T and R_t^O to be slightly lower at the end of the 1990's compared to table 9.8. Finally, by examining the supply-demand position for NR in the late 1990's, it becomes clear that, if the production trend will pertain, there may be a surplus of NR. Therefore, if the world economy will follow the rather pessimistic low economic growth scenario, NR producers should be aware of a possible surplus about 15 years from now, which, however, would again disappear after the year 2000. It needs to be stressed again that all this is based on the production policy as depicted in section 8.6. An alternative policy may give different results.

Table 9.8 *Projections of natural rubber's position in the world rubber market, scenarios G1 and P1*

	R_t^T	R_t^O	D_t^{NT}	D_t^{NO}	D_t^N	S_t^N	P_t^S	P_t^N
1980	.375	.177	2,477.3	945.7	3,760.0	3,820.0	1.32	1.63
1981	.370	.169	2,674.6	803.1	3,752.7	3,589.0	1.30	1.25
1982	.381	.171	2,721.7	852.2	3,853.9	3,716.2	1.10	1.05
1983	.392	.173	2,869.2	890.4	4,044.6	4,148.8	1.25	1.42
1984	.390	.167	2,919.1	886.2	4,095.4	4,197.5	1.30	1.43
1985	.389	.162	2,937.3	885.5	4,122.7	4,311.8	1.40	1.44
1986	.396	.161	3,070.2	906.6	4,296.8	4,407.7	1.55	1.53
1987	.403	.162	3,163.9	942.3	4,446.2	4,488.3	1.70	1.66
1988	.411	.163	3,270.0	983.4	4,613.4	4,564.1	1.85	1.83
1989	.418	.163	3,370.8	1,022.3	4,773.1	4,640.3	2.00	2.04
1990	.422	.162	3,444.8	1,052.0	4,896.8	4,729.8	2.15	2.27
1991	.418	.160	3,412.2	1,066.2	4,908.4	4,838.8	2.30	2.45
1992	.417	.157	3,440.7	1,076.9	4,977.6	4,961.9	2.45	2.65
1993	.411	.153	3,424.5	1,083.3	4,997.7	5,073.4	2.60	2.73
1994	.411	.151	3,446.0	1,098.2	5,064.2	5,199.1	2.75	2.80
1995	.409	.150	3,461.7	1,123.4	5,135.1	5,341.8	2.90	2.87
1996	.413	.150	3,479.2	1.154.4	5,233.6	5,492.7	3.05	2.91
1997	.419	.152	3,578.2	1,194.9	5,423.1	5,651.3	3.20	2.97
1998	.426	.154	3,678.7	1,242.7	5,621.4	5,805.2	3.35	3.05
1999	.435	.158	3,811.1	1,301.2	5,862.2	5,957.7	3.50	3.17
2000	.441	.161	3,919.5	1,363.4	6,082.9	6,104.0	3.65	3.32

Notes: R_t^T = share of NR in the tire sector, excl. Asian CPEC
R_t^O = share of NR in the non-tire sector, ditto
D_t^{NT} = demand for NR in the tire sector, in 1,000 tonnes, excl. Asian CPEC
D_t^{NO} = demand for NR in the non-tire sector, ditto
D_t^N = demand for NR, in 1,000 tonnes, incl. Asian CPEC
S_t^N = supply of NR, in 1,000 tonnes
P_t^S = price of SR, US $ per kg
P_t^N = price of NR, RSS1, New York, US $ per kg

Table 9.9 *Projections of natural rubber's position in the world rubber market, scenarios G1 and P2*

	R_t^T	R_t^O	D_t^{NT}	D_t^{NO}	D_t^N	S_t^N	P_t^S	P_t^N
1980	.375	.177	2,477.3	945.7	3,760.0	3,820.0	1.32	1.63
1981	.370	.169	2,674.6	803.1	3,752.7	3,589.0	1.30	1.25
1982	.381	.171	2,721.7	852.2	3,853.9	3,716.2	1.10	1.05
1983	.392	.173	2,869.2	890.4	4,044.6	4,148.8	1.25	1.42
1984	.390	.167	2,919.1	886.2	4,095.4	4,197.5	1.30	1.43
1985	.389	.162	2,937.3	885.5	4,122.7	4,329.5	1.50	1.52
1986	.397	.162	3,079.8	911.5	4,311.3	4,447.1	1.90	1.81
1987	.406	.164	3,191.5	956.3	4,487.8	4,521.1	2.30	2.16
1988	.416	.167	3,316.2	1,007.0	4,683.2	4,560.3	2.45	2.37
1989	.425	.168	3,430.0	1,052.7	4,862.7	4,637.0	2.60	2.63
1990	.431	.168	3,511.6	1,086.4	4,998.1	4,742.2	2.75	3.01
1991	.424	.163	3,457.3	1,089.6	4,976.9	4,853.9	2.90	3.36
1992	.418	.157	3,447.8	1,079.8	4,987.6	4,964.1	3.10	3.61
1993	.408	.151	3,401.5	1,069.9	4,961.4	5,071.8	3.30	3.68
1994	.404	.147	3,394.5	1,069.3	4,983.8	5,192.0	3.50	3.62
1995	.402	.145	3,401.5	1,089.2	5,040.8	5,330.6	3.70	3.60
1996	.407	.146	3,426.2	1,123.5	5,149.7	5,491.7	3.90	3.65
1997	.413	.148	3,531.9	1,167.5	5,349.4	5,650.8	4.10	3.73
1998	.421	.151	3,639.6	1,219.1	5,558.7	5,805.1	4.30	3.83
1999	.430	.155	3,770.7	1,276.6	5,797.3	5,957.4	4.50	3.97
2000	.437	.159	3,889.6	1,344.4	6,034.0	6,103.0	4.70	4.14

Notes: R_t^T = share of NR in the tire sector, excl. Asian CPEC

R_t^O = share of NR in the non-tire sector, ditto

D_t^{NT} = demand for NR in the tire sector, in 1,000 tonnes, excl. Asian CPEC

D_t^{NO} = demand for NR in the non-tire sector, ditto

D_t^N = demand for NR, in 1,000 tonnes, incl. Asian CPEC

S_t^N = supply of NR, in 1,000 tonnes

P_t^S = price of SR, US $ per kg

P_t^N = price of NR, RSS1, New York, US $ per kg

The standard demand scenario: G2

A similar analysis as for the low-growth scenario has been done for the standard scenario. Projection results in combination with the synthetic rubber price scenario P2 are given in table 9.10. Because of the higher demand pressure at given levels of the production trend from section 8.6, NR is only reaching a lower share, both in the tire sector and the non--tire sector. This causes relatively higher prices for NR in table 9.10 compared to table 9.9 .

The high-growth demand scenario: G3

If an analysis as described for the low-growth scenario and for the standard scenario is done for the high-growth scenario, there will not be a surplus of NR; on the contrary: from around 1990 onwards NR producers will not be able to supply sufficient quantities of NR to keep the price of NR competitive. This may lead to creating additional capacity of high-cis polyisoprene.

High-cis polyisoprene rubber (IR) is, like NR, an isoprene rubber, and can be considered a near-perfect substitute for NR. Up till now production costs of IR have been markedly higher than any price at which NR has ever been sold. As a near-perfect substitute for NR however, synthetic polyisoprene fetches a market price that is very close to the prevailing NR quotation.

Investment in IR plant has therefore up till now not been a profitable proposition; nevertheless some IR capacity exists, notably in the USA and the USSR. In Western countries, these plants have been created in order to secure a minimum supply of isoprene rubber, not threatened by the long supply lines of NR. The USSR may have the same security considerations, but economic autarchy, and scarcity of convertible foreign exchange, seem to be the prime reasons for the rather extensive Russian IR production.

When a supply shortage of NR increases its price considerably, and this situation is expected to last for some years, IR may become price competitive with NR. As the technology is available, additional IR capacity could be expected to be installed for purely economic reasons. Additional supply of IR would be forthcoming some time after the industry is convinced that the high NR price level is structural.

Table 9.10 *Projections of natural rubber's position in the world rubber market, scenarios G2 and P2*

	R_t^T	R_t^O	D_t^{NT}	D_t^{NO}	D_t^N	S_t^N	P_t^S	P_t^N
1980	.375	.177	2,477.3	945.7	3,760.0	3,820.0	1.32	1.63
1981	.370	.169	2,680.0	800.6	3,755.6	3,589.3	1.30	1.25
1982	.381	.171	2,738.2	844.7	3,863.0	3,717.6	1.10	1.05
1983	.392	.173	2,950.3	909.5	4,144.7	4,161.6	1.25	1.48
1984	.388	.166	3,051.7	924.2	4,265.9	4,233.3	1.30	1.56
1985	.384	.159	3,076.7	927.2	4,303.8	4,361.0	1.50	1.72
1986	.385	.153	3,206.1	943.7	4,469.7	4,471.9	1.90	2.08
1987	.385	.150	3,284.6	970.7	4,595.3	4,545.4	2.30	2.52
1988	.385	.146	3,369.7	999.2	4,728.8	4,594.4	2.45	2.88
1989	.382	.140	3,423.9	1,014.2	4,818.1	4,666.8	2.60	3.27
1990	.377	.134	3,455.6	1,020.3	4,875.9	4,747.9	2.75	3.61
1991	.366	.127	3,392.6	1,016.3	4,838.9	4,836.6	2.90	3.78
1992	.358	.121	3,399.7	1,012.8	4,872.5	4,948.8	3.10	3.88
1993	.349	.116	3,382.4	1,014.0	4,886.4	5,062.4	3.30	3.84
1994	.345	.112	3,409.0	1,025.5	4,954.5	5,188.9	3.50	3.75
1995	.342	.110	3,447.1	1,054.1	5,051.1	5,324.2	3.70	3.65
1996	.345	.111	3,503.6	1,098.5	5,202.1	5,494.6	3.90	3.72
1997	.349	.112	3,640.4	1,150.1	5,440.6	5,655.7	4.10	3.83
1998	.354	.113	3,777.4	1,207.4	5,684.8	5,811.4	4.30	3.98
1999	.359	.114	3,935.0	1,268.9	5,953.9	5,964.7	4.50	4.17
2000	.362	.116	4,078.0	1,338.1	6,216.1	6,110.9	4.70	4.40

Notes: R_t^R = share of NR in the tire sector, excl. Asian CPEC

R_t^O = share of NR in the non-tire sector, ditto

D_t^{NT} = demand for NR in the tire sector, in 1,000 tonnes, excl. Asian CPEC

D_t^{NO} = demand for NR in the non-tire sector, ditto

D_t^N = demand for NR,in 1,000 tonnes, incl. Asian CPEC

S_t^N = supply of NR, in 1,000 tonnes

P_t^S = price of SR, US $ per kg

P_t^N = price of NR, RSS1, New York, US $ per kg

In the analysis described below, it has been assumed that polyisoprene (IR) will further replace NR if the price of NR, originating from the demand--supply position of NR, is higher than or equal to a reasonable level of the cost price of polyisoprene. The polyisoprene cost price is supposed to be related to the price of SBR. At a very low NR price, economic IR production would cease. It is assumed, however, that the presently existing IR capacity, which has been created for non-economic reasons, would remain.

In this context it must be made clear that thus far D_t^N represents total demand for isoprene rubber (natural or synthetic) minus synthetic high-cis polyisoprene supply already in existence nowadays, which is supplied for non-economic reasons, as argued above. Thus D_t^N only meant demand for natural rubber. Under the demand scenario G3 it is possible that synthetic polyisoprene capacity is created because it is profitable in view of the high NR prices. Clearly, the expected shares are not really affected by the origin of the isoprene supply (NR or IR). The supply of synthetic IR (S_t^I) as far as it is created during the projection period, is deducted from total demand for isoprene rubbers in order to obtain demand for natural rubber, which, in combination with supply of NR, influences the price of NR.

A combination of the high-growth scenario G3 with the SR price scenario P3 seems logical. Projection results are shown in table 9.11. Natural rubber becomes very scarce in the middle of the eighties, resulting in a high level of P_t^N. As in the case of the low-growth scenario, it is not realistic that P_t^S does not follow, in the short-run, the price of NR. The result is a drop in the joint share of NR+IR, both in the tire sector and the non-tire sector, until the middle of the 1990's. This happens in spite of synthetic IR adding some 4 percent to NR supply. Of course, this could only happen because NR was very expensive while supply S_t^I is fixed, given its capacity created in the past. S_t^I is henceforth supplied at the price level of NR, even when its cost price may be higher. This happens in particular from the middle of the 1990's onwards, when a considerable increase in supply comes to the market, according to the production policy, assumed in section 8.6. It needs to be stressed that a different production policy regarding new planting, replanting and uprooting of rubber land, would result in a different picture especially for the 1990's. Many of such alternative production policies may be tested using the framework of this analysis.

Table 9.11 *Projections of natural rubber's position in the world rubber market, scenarios G3 and P3*

	R_t^T	R_t^O	D_t^{IRT}	D_t^{IRO}	D_t^{NC}	D_t^{IR}	S_t^I	D_t^N	S_t^N	P_t^S	P_t^{Ic}	P_t^{Nu}	P_t^N
1980	.375	.177	2,477.3	945.7	337.0	3,760.0	0.0	3,760.0	3,820.0	1.32	2.02	1.63	1.63
1981	.370	.169	2,685.3	798.2	275.0	3,758.5	0.0	3,758.5	3,589.7	1.30	1.99	1.25	1.25
1982	.381	.171	2,752.7	838.3	280.0	3,871.0	0.0	3,871.0	3,719.0	1.10	1.73	1.05	1.05
1983	.392	.173	3,034.3	931.3	285.0	4,250.7	0.0	4,250.7	4,174.5	1.25	1.93	1.53	1.53
1984	.387	.165	3,193.4	967.1	290.0	4,450.6	0.0	4,450.6	4,314.9	1.50	2.25	2.04	2.04
1985	.380	.156	3,231.7	976.4	300.0	4,508.1	0.0	4,508.1	4,407.4	1.80	2.64	2.51	2.51
1986	.376	.147	3,362.4	992.0	320.0	4,674.3	50.0	4,624.3	4,480.1	2.10	3.03	3.10	3.03
1987	.369	.139	3,421.1	1,006.4	340.0	4,767.5	210.0	4,557.5	4,519.4	2.30	3.29	3.50	3.28
1988	.362	.131	3,481.2	1,021.5	360.0	4,862.7	230.0	4,632.7	4,585.8	2.50	3.55	3.58	3.55
1989	.355	.124	3,535.8	1,036.6	380.0	4,952.4	260.0	4,692.4	4,651.4	2.70	3.81	3.84	3.80
1990	.349	.117	3,588.3	1,052.2	400.0	5,040.5	260.0	4,780.5	4,736.4	2.90	4.07	4.06	4.06
1991	.339	.111	3,553.6	1,061.4	430.0	5,045.0	260.0	4,785.0	4,838.3	3.20	4.46	4.27	4.27
1992	.331	.106	3,600.5	1,074.1	460.0	5,134.6	260.0	4,874.6	4,953.1	3.50	4.85	4.44	4.44
1993	.323	.102	3,624.3	1,092.3	490.0	5,206.6	260.0	4,946.6	5,074.1	3.80	5.24	4.56	4.56
1994	.319	.098	3,692.2	1,118.9	520.0	5,331.0	260.0	5,071.0	5,208.5	4.10	5.63	4.67	4.67
1995	.314	.095	3,757.7	1,155.1	550.0	5,462.8	260.0	5,202.8	5,351.3	4.40	6.02	4.78	4.78
1996	.313	.094	3,817.7	1,195.7	600.0	5,613.3	260.0	5,353.3	5,497.0	4.60	6.28	4.82	4.82
1997	.313	.093	3,968.4	1,245.3	650.0	5,863.7	260.0	5,603.7	5,662.0	4.80	6.54	4.97	4.97
1998	.314	.092	4,119.8	1,299.7	700.0	6,119.5	260.0	5,859.5	5,822.8	5.00	6.80	5.23	5.23
1999	.314	.091	4,284.2	1,352.9	750.0	6,387.1	260.0	6,127.1	5,981.8	5.20	7.06	5.62	5.62
2000	.311	.090	4,409.7	1,399.4	800.0	6,609.0	260.0	6,349.0	6,130.7	5.40	7.32	6.07	6.07

Notes:
R_t^T = share of NR+IR in the tire sector, excl. Asian CPEC
R_t^O = share of NR+IR in the non-tire sector, ditto
D_t^{IRT} = demand for NR+IR in the tire sector, in 1,000 tonnes, excl. Asian CPEC
D_t^{IRO} = demand for NR+IR in the non-tire sector, ditto
D_t^{NC} = demand for NR in Asian CPEC, in 1,000 tonnes
D_t^{IR} = total demand for NR+IR, in 1,000 tonnes
S_t^I = supply of synthetic IR, in 1,000 tonnes, see text
D_t^N = total demand for NR, in 1,000 tonnes
S_t^N = supply of NR, in 1,000 tonnes
P_t^S = price of SR, US \$ per kg, see text
P_t^{Ic} = cost price of synthetic IR, US \$ per kg
P_t^{Nu} = price of NR, US \$ per kg, if ΔS_t^I would equal zero
P_t^N = price of NR, US \$ per kg
IR = NR + SIR
SIR = synthetic IR

9.4 CONCLUSION

The first half of the study on "The world rubber economy to the year 2000" leads to levels of prospective demand for rubber in total. In view of uncertainties about the future of the world economy, three demand scenarios have been derived: G1, G2 and G3. On the supply side projections have been made using one set of assumptions on production policies for the future. The question: "Is this production policy optimal?", can only be answered conditional upon the demand scenarios G1, G2 and G3 and keeping in mind the problems about the inclusion of short-term movements in $\hat{P}$ in the SR price.

The most likely scenario, the standard scenario G2, in combination with the supply projections, would result in NR seeing its share in the non-tire sector reduce to levels of around 11 percent, while in the tire sector the NR share would fall, starting in the late 1980's. More supply would have led to a somewhat lower price but a higher share.

The pessimistic low-growth demand scenario G1 would still show all NR supply to be absorbed with a slight decrease in the NR share in the non-tire sector and some increase in the tire sector NR share. For the optimistic demand scenario G3, there will certainly not be enough NR, if the supply projections would come true. A strong increase in NR production would then be necessary to keep NR competitive.

APPENDIX A: SCENARIOS FOR POPULATION, INCOME AND ENERGY

Any model deals with two types of variables: variables whose development is explained by the model (e.g. car-ownership) and variables which are very important to the model but whose development must be analyzed in a greater context (e.g. income growth). Variables of the latter type cannot be "explained" in a sector- or commodity-specific study like the present one, but are assumed to be given exogenously.

The ultimate determinants of world demand for rubber are population, national incomes and their respective growth rates. The basic connection between these key variables and such rubber-using products as vehicles, tires and other rubber goods is self-evident. Projections of these fundamental demand determinants introduce, however, a somewhat arbitrary element in rubber demand projections. The plausibility of the assumptions with respect to population and income growth determines the validity of the result of any study.

a. *Population*

The population projections used in the present study are those of the so-called United Nations Medium Variant (see United Nations, Population Division (1975)). Some adjustments have been made by us to account for recent developments in population growth. A summary is given below in table A.1.

b. *Income*

There is considerable uncertainty over the future of world income levels. Because of the controversy surrounding such long-term projections, we have devised three alternative scenarios of future economic growth, projecting Gross Domestic Product (GDP) in 1975 prices, in 1975 US $ by country or region:

Table A.1 *Population estimates and projections by broad regions (in millions)*

Country	1975	1980	1985	1990	1995	2000
1. USA	216.0	227.7	240.8	253.9	266.3	277.9
2. Canada	22.7	23.9	25.2	26.4	27.6	28.7
3. Japan	111.6	116.8	120.6	123.4	125.7	127.3
4. Australia	13.8	14.6	15.7	16.8	17.8	18.9
5. New Zealand	3.1	3.1	3.1	3.1	3.1	3.1
6. Germany F.R.	61.8	61.6	61.9	62.2	62.5	62.8
7. France	52.8	53.7	54.7	55.4	55.8	56.0
8. United Kingdom	55.9	55.9	56.4	56.9	57.5	58.1
9. Netherlands	13.7	14.1	14.7	15.3	15.8	16.4
10. Belgium + Luxembourg	10.2	10.2	10.3	10.3	10.3	10.4
11. Denmark	5.1	5.1	5.2	5.2	5.2	5.2
12. Iceland	.2	.2	.2	.2	.2	.3
13. Sweden	8.2	8.3	8.4	8.5	8.5	8.6
14. Switzerland	6.4	6.4	6.4	6.5	6.5	6.6
15. Ireland	3.2	3.4	3.6	3.8	4.0	4.1
16. Norway	4.0	4.1	4.2	4.2	4.3	4.3
17. Finland	4.7	4.8	4.8	4.9	4.9	5.0
18. Austria	7.5	7.5	7.5	7.5	7.5	7.5
19. Italy	55.8	57.0	58.0	58.8	59.5	60.2
20. Spain	35.6	37.4	39.2	40.9	42.4	43.8
21. Portugal	9.4	9.9	10.3	10.6	10.9	11.2
22. Greece	9.1	9.6	10.1	10.6	11.0	11.5
23. Turkey	40.0	44.9	50.6	56.3	61.8	67.1
24. Yugoslavia	21.4	22.3	23.2	24.0	24.7	25.2
25. Other Western Europe	.5	.5	.5	.6	.6	.6
26. USSR	254.5	265.5	275.5	284.4	292.2	298.7
27. Czechoslovakia	14.8	15.3	15.8	16.3	16.7	17.0
28. Germany D.R.	16.9	16.7	16.7	16.6	16.6	16.6
29. Hungary	10.5	10.7	10.8	10.9	11.0	11.1
30. Poland	34.0	35.6	37.1	38.6	39.9	41.0
31. Romania	21.3	22.3	23.3	24.4	25.5	26.6
32. Other Eastern Europe	11.1	11.6	12.0	12.3	12.6	12.9
33. Brazil	106.2	123.0	141.0	160.7	182.4	206.0
34. Argentina	25.4	27.1	28.6	30.1	31.4	32.5
35. Mexico	60.2	71.9	85.7	101.5	119.8	140.6
36. Other Latin America	125.8	141.0	157.7	176.0	195.9	217.6
37. China	895.3	956.9	1010.6	1059.0	1104.3	1145.7
38. Other Asian CPEC	88.7	99.8	111.8	124.3	137.1	150.2
39. India	600.8	663.6	726.9	790.5	853.2	914.2
40. Bangladesh	79.0	87.7	98.0	109.1	120.8	133.1
41. Pakistan	70.3	82.4	96.2	111.5	128.3	146.5
42. Sri Lanka	13.5	14.7	16.1	17.6	19.3	21.1
43. Other South Asia	42.8	49.3	54.9	60.8	67.0	73.4
44. Indonesia	135.2	151.9	169.7	188.6	208.7	229.7
45. Malaysia	11.9	13.5	15.2	16.9	18.6	20.1
46. Philippines	42.3	48.4	55.2	62.1	69.1	75.9
47. Thailand	41.9	47.2	52.4	57.9	63.4	68.9
48. Singapore	2.3	2.4	2.5	2.6	2.7	2.8
49. Hong Kong	4.4	5.1	5.5	5.9	6.3	6.7
50. Korea	35.3	38.1	41.1	44.1	47.0	49.9
51. Other Oceania	4.0	4.5	5.1	5.7	6.3	7.0
52. Other Asia	16.2	17.5	18.9	20.3	21.9	23.6
53. Iran	33.4	37.4	42.3	47.5	53.1	59.1
54. Other oil	43.7	50.5	58.2	66.7	76.0	86.3
55. Other Middle East + North Africa	78.8	90.5	103.6	117.7	132.8	148.7
56. Nigeria	65.7	77.1	91.0	107.6	127.2	150.3
57. South Africa	25.5	29.3	33.7	38.6	44.0	49.9
58. Other Africa	287.0	332.7	385.7	447.1	518.4	600.9

Scenario G1 - low rate of economic growth
G2 - medium rate of economic growth (standard scenario)
G3 - high rate of economic growth.

The assumptions behind these scenarios are as follows:
- growth figures are based on projections by national institutes and by such organizations as the OECD
- if no recent projections are available, the pattern of recent years is used and extrapolated with an adjustment for the world economic recession
- around these basic projections of economic growth a low-, a medium- and a high economic growth scenario have been drawn up
- from 1982 onwards growth rates are in general assumed to increase until the second half of the 1980's
- all growth figures for 1982 and later are rounded at 0.5 percent.

The advantage of these alternative scenarios in projecting world demand for rubber is that they permit the individual reader:

a. to include his own views concerning the future of the world economy into his projection-based decisions;
b. to adjust his choice of projection as new information on the world's economic future becomes available; and
c. to draw conclusions about the sensitivity of the demand for rubber to the rate of economic growth and the consequences of these economic growth scenarios for the results of production policies.

The three projected GDP scenarios are presented in detail in table A.2. Developments in aggregate world GDP are shown in figure A.1.

c. *Energy*

The last part of our macro scene is the energy aspect. We shall just mention a few sections of the analysis where energy may come to the forefront:

a - economic growth
b - passenger car and commercial vehicle park
c - driving distance and discarding
d - driving distance and tire wear
e - increased usage of retreaded tires
f - production costs and, thus, prices of SR
g - prices and production costs of NR.

It needs no further clarification that it is very hard to include the energy aspect accurately into the model because

- it is not clear what the relationships are
- it is not clear what the future of energy will be.

For example, energy availability and price affect GDP growth which in turn influences passenger car-ownership. But passenger car-ownership may be more sensitive to energy (oil) availability than GDP in general. On the other hand, perhaps driving distance rather than car-ownership is affected by oil availability and price.

Consequently, quantifying energy scenarios, as has been done above for GDP, and then determining exact relationships with variables like driving distance, seems an impossible venture. We shall therefore confine ourselves to qualitatively mentioning energy (oil) scenarios and assume possible effects wherever necessary. These scenarios may be described along the following lines:

scenario	*price*
E1	high
E2	low

Further details have been tentatively quantified wherever necessary in the various chapters and projections.

Table A.2 *Scenarios for economic growth, estimates and projections (percentages, in 1975 constant prices)*

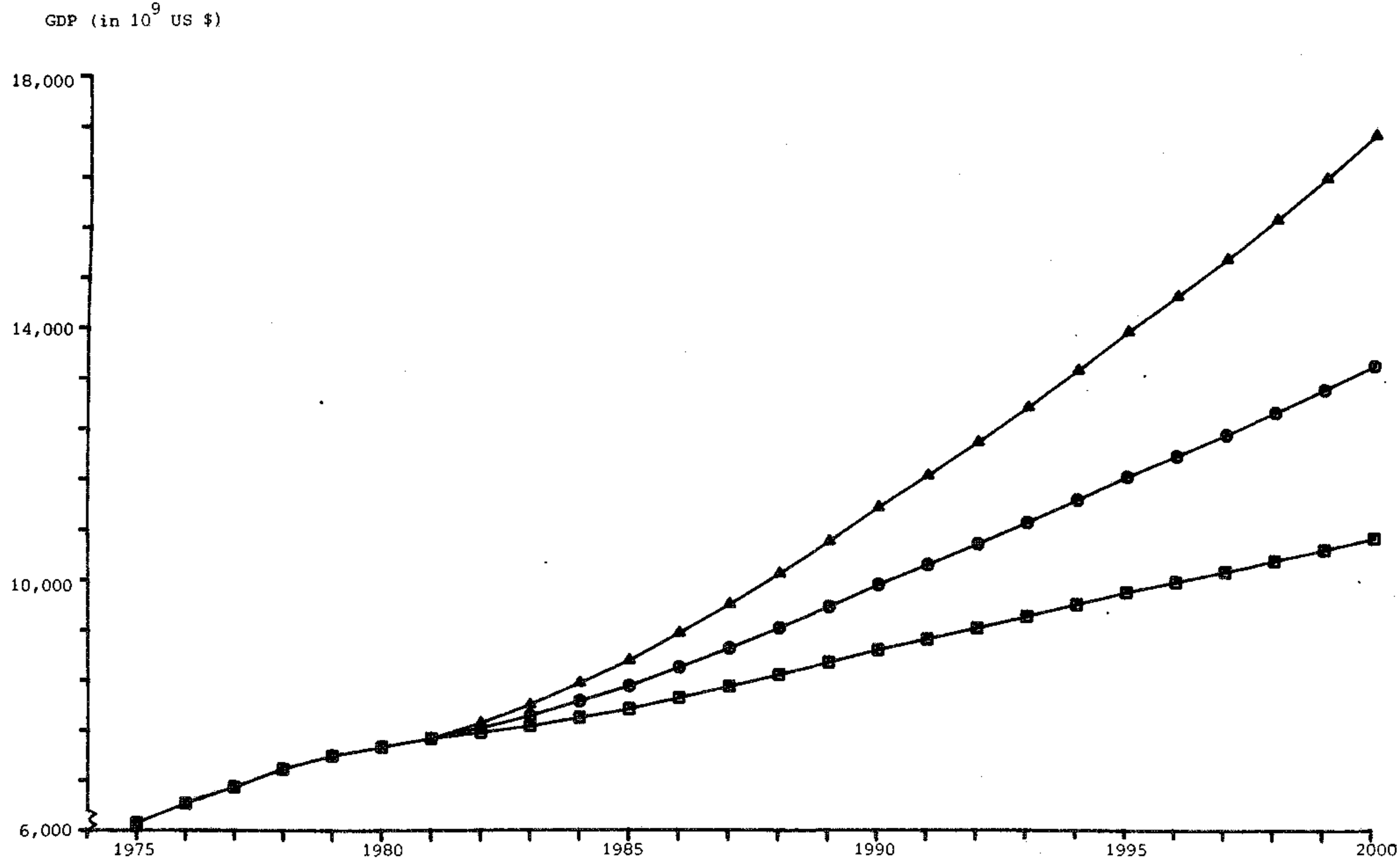
		1980	1981	1982	1983	1984/1985	1986/1990	1991/1995	1996/2000
1. USA	G1	-.10	1.75	1.0	1.0	1.5	2.0	1.5	1.0
	G2			2.0	2.5	3.0	3.5	3.0	2.5
	G3			3.0	4.0	4.5	5.0	4.5	4.0
2. Canada	G1	0	3.0	2.0	2.0	2.0	2.5	2.0	1.5
	G2			3.0	3.5	3.5	4.0	3.5	3.0
	G3			4.0	5.0	5.0	5.5	5.0	4.5
3. Japan	G1	4.40	3.75	3.5	3.5	3.5	4.0	3.5	3.0
	G2			5.0	5.0	5.0	5.5	5.0	4.5
	G3			6.5	6.5	6.5	7.0	6.5	6.0
4. Australia	G1	1.78	3.0	2.0	2.0	2.0	2.0	1.5	1.0
	G2			3.0	3.0	3.0	3.5	3.0	2.5
	G3			4.0	4.0	4.0	5.0	4.5	4.0
5. New Zealand	G1	2.51	2.25	1.5	1.5	1.5	1.5	1.0	1.0
	G2			2.0	2.0	2.5	2.5	2.0	1.5
	G3			2.5	2.5	3.5	3.5	3.0	2.0
6. Germany F.R.	G1	1.91	-1.0	-1.0	-0.5	0	0.5	0	0
	G2			0	0.5	1.0	1.5	1.0	0.5
	G3			1.5	2.0	2.5	3.0	2.5	1.5
7. France	G1	1.16	0.5	0	0	0	0.5	0	0
	G2			0.5	0.5	1.0	1.5	1.0	0.5
	G3			1.5	1.5	2.5	3.0	2.5	1.5
8. United Kingdom	G1	-1.36	-2.0	-2.0	-1.5	-0.5	0	0	-0.5
	G2			-1.0	-0.5	0.5	1.0	0.5	0
	G3			0.5	1.0	2.0	2.5	1.5	1.0
9. Netherlands	G1	0.56	-2.0	-2.0	-1.5	-0.5	0	0	-0.5
	G2			-1.0	-0.5	0.5	1.0	0.5	0
	G3			0.5	1.0	2.0	2.5	1.5	1.0
10. Belgium : Luxemburg	G1	2.51	-1.25	-1.5	-1.0	0	0.5	0	0
	G2			-0.5	0	1.0	1.5	1.0	0.5
	G3			1.0	1.5	2.5	3.0	2.5	1.5
11. Denmark	G1	-0.23	-0.50	-0.5	-0.5	0	0.5	0	0
	G2			0	0.5	1.5	2.0	1.5	1.0
	G3			1.0	2.0	3.5	4.0	3.5	2.5
12. Iceland	G1	2.63	1.25	0.5	0.5	1.0	1.0	1.0	0.5
	G2			1.5	1.5	2.0	2.5	2.0	1.5
	G3			2.5	2.5	3.0	4.0	3.0	2.5
13. Sweden	G1	1.42	0	-0.5	0	0.5	0.5	0.5	0
	G2			0.5	1.0	1.5	2.0	1.5	1.0
	G3			2.0	2.5	3.0	4.0	3.0	2.5
14. Switzerland	G1	-4.39	4.0	2.5	2.5	2.5	3.0	2.5	2.0
	G2			4.0	4.0	4.0	4.5	4.0	3.5
	G3			5.5	5.5	5.5	6.0	5.5	5.0
15. Ireland	G1	1.83	2.0	1.5	1.5	1.5	2.0	1.5	1.0
	G2			2.0	2.0	2.0	2.5	2.0	1.5
	G3			2.5	2.5	2.5	3.0	2.5	2.0
16. Norway	G1	3.78	1.5	1.0	1.0	1.5	1.5	1.0	1.0
	G2			1.5	2.0	2.5	3.0	2.5	2.0
	G3			2.0	3.0	3.5	4.5	4.0	3.0
17. Finland	G1	5.02	1.75	1.0	1.0	1.5	1.5	1.5	1.0
	G2			2.0	2.0	2.5	3.0	2.5	2.0
	G3			3.0	3.0	3.5	4.5	3.5	3.0
18. Austria	G1	3.11	0	-0.5	0	0	0.5	0	0
	G2			0	0.5	1.0	1.5	1.0	0.5
	G3			1.0	1.5	2.5	3.0	2.5	1.5
19. Italy	G1	3.96	0	-0.5	0	0	0.5	0	0
	G2			0	0.5	1.0	1.5	1.0	0.5
	G3			1.0	1.5	2.5	3.0	2.5	1.5

Table A.2 (continued)

		1980	1981	1982	1983	1984/ 1985	1986/ 1990	1991/ 1995	1996/ 2000
20. Spain	G1	1.20	1.5	1.0	1.0	1.0	1.5	1.0	0.5
	G2			1.5	2.0	2.0	2.5	2.0	1.5
	G3			2.0	3.0	3.0	3.5	3.0	2.5
21. Portugal	G1	5.51	2.5	2.0	2.0	2.0	2.5	2.0	1.5
	G2			2.5	2.5	3.0	3.5	3.0	2.5
	G3			3.0	3.0	4.0	4.5	4.0	3.5
22. Greece	G1	1.66	-0.25	-0.5	0	0	0.5	0.5	0
	G2			0	0.5	1.0	1.5	1.0	0.5
	G3			1.0	1.5	2.5	3.0	2.0	1.5
23. Turkey	G1	-0.58	4.0	2.5	2.5	2.5	3.0	2.5	2.0
	G2			3.5	3.5	4.0	4.5	4.0	3.5
	G3			4.5	4.5	5.5	6.0	5.5	5.0
24. Yugoslavia	G1	5.0	4.0	3.0	3.0	3.0	3.5	3.0	2.5
	G2			4.0	4.0	4.0	4.5	4.0	3.5
	G3			5.0	5.0	5.0	5.5	5.0	4.5
25. Other Western Europe	G1	6.0	5.0	3.5	3.5	3.5	3.5	3.0	2.5
	G2			4.0	4.0	4.0	4.5	4.0	3.5
	G3			4.5	4.5	4.5	5.5	5.0	4.5
26. USSR	G1	3.0	3.0	2.0	2.0	2.5	2.5	2.5	2.0
	G2			3.0	3.0	3.5	4.0	3.5	3.0
	G3			4.0	4.0	4.5	5.5	4.5	4.0
27. Czechoslovakia	G1	2.76	2.5	2.0	2.0	2.0	2.5	2.0	1.5
	G2			2.5	2.5	3.0	3.5	3.0	2.5
	G3			3.0	3.0	4.0	4.5	4.0	3.5
28. Germany, D.R.	G1	4.19	4.0	3.0	3.0	3.0	3.5	3.0	2.5
	G2			4.0	4.0	4.0	4.5	4.0	3.5
	G3			5.0	5.0	5.0	5.5	5.0	4.5
29. Hungary	G1	-0.65	-0.5	-0.5	-0.5	0	0.5	0	-0.5
	G2			0	0	0.5	1.0	0.5	0
	G3			1.0	1.0	1.5	2.0	1.5	1.0
30. Poland	G1	-6.00	-6.0	-5.5	-3.5	-1.5	0.5	0	0
	G2			-4.0	-2.0	0	2.0	1.5	1.0
	G3			-2.0	0	2.0	4.0	3.5	2.5
31. Romania	G1	2.93	2.0	1.0	1.5	1.5	2.0	1.5	1.0
	G2			2.0	2.5	2.5	3.0	2.5	2.0
	G3			3.0	3.5	3.5	4.0	3.5	3.0
32. Other Eastern Europe	G1	5.7	4.0	3.0	3.0	3.0	3.5	3.0	2.5
	G2			4.0	4.0	4.0	4.5	4.0	3.5
	G3			5.0	5.0	5.0	5.5	5.0	4.5
33. Brazil	G1	5.0	4.0	3.0	3.5	3.5	3.5	3.5	3.0
	G2			4.0	4.5	4.5	5.0	4.5	4.0
	G3			5.0	5.5	5.5	6.5	5.5	5.0
34. Argentina	G1	-0.50	-0.5	-0.5	-0.5	-0.5	0	-0.5	-0.5
	G2			0	0	0.5	1.0	0.5	0
	G3			1.0	1.0	2.0	2.5	2.0	1.0
35. Mexico	G1	7.0	6.0	4.5	4.5	4.5	5.0	4.5	4.0
	G2			6.0	6.0	6.0	6.5	6.0	5.5
	G3			7.5	7.5	7.5	8.0	7.5	7.0
36. Other Latin America	G1	4.2	4.0	3.0	3.0	3.0	3.5	3.0	2.5
	G2			4.0	4.0	4.0	4.5	4.0	3.5
	G3			5.0	5.0	5.0	5.5	5.0	4.5
37. China	G1	1.2	1.5	1.0	1.0	1.0	1.5	1.0	0.5
	G2			1.5	1.5	2.0	2.5	2.0	1.5
	G3			2.0	2.0	3.0	3.5	3.0	2.5
38. Other Asian CPEC	G1	0.5	0.5	0	0	0	0.5	0	0
	G2			0.5	0.5	1.0	1.5	1.0	0.5
	G3			1.5	1.5	2.5	3.0	2.5	1.5
39. India	G1	1.0	1.0	0.5	0.5	1.0	1.0	1.0	0.5
	G2			1.0	1.5	2.0	2.5	2.0	1.5
	G3			2.0	3.0	3.5	4.5	3.5	3.0

Table A.2 (continued)

			1980	1981	1982	1983	1984/ 1985	1986/ 1990	1991/ 1995	1996/ 2000
40.	Bangladesh	G1	4.0	3.0	2.5	2.5	2.5	3.0	2.5	2.0
		G2			3.0	3.0	3.5	4.0	3.5	3.0
		G3			3.5	3.5	4.5	5.0	4.5	4.0
41.	Pakistan	G1	5.78	5.0	4.0	4.0	4.0	4.5	4.0	3.5
		G2			5.0	5.0	5.0	5.5	5.0	4.5
		G3			6.0	6.0	6.0	6.5	6.0	5.5
42.	Sri Lanka	G1	5.0	5.0	4.0	4.0	4.5	4.5	4.5	4.0
		G2			5.0	5.0	5.5	6.0	5.5	5.0
		G3			6.0	6.0	6.5	7.5	6.5	6.0
43.	Other South Asia	G1	4.0	4.0	3.0	3.0	3.5	4.0	3.5	3.0
		G2			4.0	4.0	4.5	5.0	4.5	4.0
		G3			5.0	5.0	5.5	6.0	5.5	5.0
44.	Indonesia	G1	9.65	9.6	5.0	5.0	5.0	5.5	5.0	4.5
		G2			6.0	6.0	6.5	7.0	6.5	6.0
		G3			7.0	7.0	8.0	8.5	8.0	7.5
45.	Malaysia	G1	7.66	6.9	6.0	6.0	6.0	6.5	6.0	5.5
		G2			7.0	7.0	7.0	7.5	7.0	6.5
		G3			8.0	8.0	8.0	8.5	8.0	7.5
46.	Philippines	G1	5.82	5.5	4.5	4.5	4.5	5.0	4.5	4.0
		G2			5.5	5.5	5.5	6.0	5.5	5.0
		G3			6.5	6.5	6.5	7.0	6.5	6.0
47.	Thailand	G1	6.32	7.8	6.0	6.0	6.0	6.5	6.0	5.5
		G2			7.0	7.0	7.0	7.5	7.0	6.5
		G3			8.0	8.0	8.0	8.5	8.0	7.5
48.	Singapore	G1	10.20	9.7	8.0	8.0	8.5	9.0	8.5	8.0
		G2			9.0	9.0	9.5	10.0	9.5	9.0
		G3			10.0	10.0	10.5	11.0	10.5	10.0
49.	Hong Kong	G1	9.0	10.4	7.5	7.5	7.5	7.5	7.0	7.0
		G2			8.0	8.0	8.0	8.5	8.0	7.5
		G3			8.5	8.5	8.5	9.5	9.0	8.0
50.	Korea	G1	-3.41	7.1	5.5	5.5	5.5	6.0	5.5	5.0
		G2			7.0	7.0	7.0	7.5	7.0	6.5
		G3			8.5	8.5	8.5	9.0	8.5	8.0
51.	Other Oceania	G1	1.0	1.0	0	0	0.5	1.0	0.5	0
		G2			1.0	1.0	1.5	2.0	1.5	1.0
		G3			2.0	2.0	2.5	3.0	2.5	2.0
52.	Other Asia	G1	7.0	5.5	6.0	6.0	6.0	6.5	6.0	5.5
		G2			7.5	7.5	7.5	8.0	7.5	7.0
		G3			9.0	9.0	9.0	9.5	9.0	8.5
53.	Iran	G1	0	0	0	0	0	0.5	0	0
		G2			0.5	0.5	1.0	1.5	1.0	0.5
		G3			1.5	1.5	2.5	3.0	2.5	1.5
54.	Other oil	G1	4.0	4.0	3.0	3.0	3.0	3.5	3.0	2.5
		G2			4.0	4.0	4.5	5.0	4.5	4.0
		G3			5.0	5.0	6.0	6.5	6.0	5.5
55.	Other Middle East + North Africa	G1	6.5	6.5	5.5	5.5	6.0	6.0	6.0	5.5
		G2			6.5	6.5	7.0	7.5	7.0	6.5
		G3			7.5	7.5	8.0	9.0	8.0	7.5
56.	Nigeria	G1	9.0	7.0	6.0	6.0	6.5	6.5	6.5	6.0
		G2			7.0	7.0	7.5	8.0	7.5	7.0
		G3			8.0	8.0	8.5	9.5	8.5	8.0
57.	South Africa	G1	8.12	5.0	3.5	3.5	3.5	4.0	3.5	3.0
		G2			5.0	5.0	5.0	5.5	5.0	4.5
		G3			6.5	6.5	6.5	7.0	6.5	6.0
58.	Other Africa	G1	0	0	-0.5	-0.5	0	0.5	0	-0.5
		G2			0	0.5	1.0	1.5	1.0	0.5
		G3			1.0	2.0	2.5	2.0	2.5	2.0



<u>Figure A.1</u> *Developments in aggregate world GDP for three scenarios (10^9 1975 US dollars)*

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